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REACTIONS OF THE PHOSPHORUS OF THE THICKENED ROOT OF THE FLAT TURNIP[1]

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INTRODUCTION

In earlier publications of the Rhode Island Agricultural Experiment Station (4, 7)[2] it was shown that the percentage of total phosphorus in flat-turnip roots (*Brassica rapa* L.) grown in different soils generally varied in the same direction as the variation in the amount of phosphorus which was available to the plant. The work herein recorded represents a study of the reactions, to various reagents and treatments, of different portions of the phosphorus in turnip roots, mainly for the purpose of ascertaining whether the variation in the percentage of phosphorus in roots from different soils is limited to certain of the groups of phosphorus compounds or is distributed proportionately among them all. This information was expected to throw light upon the question as to whether a determination of the total amount of phosphorus, or the amount in some particular group of phosphorus compounds, would be most useful in attempting to ascertain whether or not there existed sufficient phosphorus at the disposal of the plant.

ANALYSIS OF DRIED TURNIPS

To secure preliminary indications, the following work was done in 1907 with samples of turnips from different localities where there were found by soil tests to be wide differences in the amount of available phosphorus.

Dried turnips which had been ground to particles less than 1 mm. in diameter were first extracted with ether in a Soxhlet apparatus. As scarcely more than traces of phosphorus proved to be soluble in this solvent, the ether was removed, and the extraction continued with 95 per cent alcohol. These two extracts were united and evaporated and

[1] Contribution No. 235 from the Rhode Island Agricultural Experiment Station.

[2] Reference is made by number to "Literature cited," p. 370.

the phosphorus determined after ignition with magnesium nitrate, as has usually been done in connection with determining total phosphorus. The residue from the ether-alcohol extraction was treated successively at room temperature with five portions of 0.2 per cent hydrochloric acid. Each portion was allowed to stand at least 24 hours, with frequent stirring. In this extract was determined, in separate aliquots, the total phosphorus, that which was precipitated directly by molybdenum mixture according to the method used by Hart and Andrews (2) for determining "inorganic" phosphorus, as well as that precipitated by alcohol. The amount of phosphorus in the residue from the extractions was likewise determined. The results are given in Table I.

TABLE I.—*Percentage of phosphorus pentoxid in dry flat turnips*

Flat turnips—	Percentage of phosphorus pentoxid.	Fractional solubilities expressed as percentages of total phosphorus pentoxid—				
		In ether and alcohol.	In 0.2 per cent hydrochloric acid.		Residue from preceding solvents.	Total.
			Precipitated by molybdenum mixture.	Precipitated by alcohol.		
From soil unmanured with phosphorus	0.45	13	55	16	16	100
From the same soil manured with an insoluble phosphate	.45	11	48	20	21	100
From the same soil manured with bone	.87	9	73	11	7	100
From soil containing very little available phosphorus	.27	10	53	20	17	100
From soil containing a medium amount of available phosphorus	.60	11	59	9	21	100
From soil containing much available phosphorus	1.14	10	66	8	16	100

It may be noticed, in case of the hydrochloric-acid extract of the turnips referred to, that larger proportions of phosphorus precipitated directly by molybdenum mixture are exhibited in the third column of the table (73 and 66 per cent) than in the others. These samples were grown in soils well supplied with available phosphorus, and the suggestion was thus received that possibly a plentiful amount of available phosphorus in the soil results in an increased proportion of that part of the phosphorus which has sometimes been classed as inorganic. The work of Koch and Reed (9), which included the growing of *Aspergillus niger* in nutrient solutions containing a very small as well as increasing amounts of phosphorus, was published at the time the preliminary work was going on and was of interest in the same connection. They found that the ratio of the protein phosphorus to the water-soluble or extractive phos-

phorus in the plant was 100 to 17 when the minimum amount of phosphorus was supplied and about 100 to 300 when there was a liberal amount. On account of the indications that possibly an increased percentage of phosphorus in the turnip root may be due in a considerable degree to an accumulation of inorganic phosphorus, attention was turned principally to the aqueous extractive portion rather than to the lipoid and residual portions, which constitute only minor parts of the phosphorus of the turnip roots.

It is shown by the following work that a more complete aqueous extraction of phosphorus can be made of the fresh pulp than of the dried turnip: 300-gm. lots from the same turnips were in two cases dried in slices at about 60° C., finely ground, and then digested for 36 hours, one with 800 gm. of distilled water and the other with 0.2 per cent hydrochloric acid; and in another case the undried pulp was digested similarly for 36 hours with about 475 gm. of distilled water, which with that in the turnips equaled the amount used to extract the dried turnips. The amount of extracted phosphorus pentoxid, in grams per 100 of dry turnip, was, with water, 0.561 from the fresh pulp and 0.500 from the dried material; whereas it was only 0.414 when the hydrochloric acid was used as a solvent with the dried material.

To avoid the changes which apparently take place during the drying of turnips, attention was next turned to a study of fresh turnips, including some of the transformations which occur in connection with the living cells.

MICROCHEMICAL EXAMINATIONS

A number of similar turnips which had been grown in soil in the greenhouse until the thickened roots were 1 to 2 inches in diameter were transferred to a nutrient solution in bottles. After the turnips had become adjusted to the new conditions some of them were deprived of phosphorus in the nutrient solution. Six days later it was found upon examination of one of these for phosphorus with a modified magnesium mixture containing only a small amount of ammonium hydroxid that practically no crystals of ammonium magnesium phosphate existed in microscopic sections, whereas similar turnips from which the phosphorus had not been withheld contained an abundance of them. An examination of the culture solution to which no phosphorus had been added showed that the phosphorus originally precipitable by the magnesium mixture had not passed out into the solution; therefore it probably had been used in the nutrition of the plant.

Some of the turnips which had been deprived of phosphorus were next supplied with liberal amounts in the nutrient solution, so that from time to time one of them might be examined for evidences of phosphorus absorption. Within 24 hours after phosphorus had been added in the nutrient solution crystals of ammonium magnesium phosphate were

readily formed upon adding magnesium mixture to certain parts of the tissues.[1]

Repeated examinations for the relative abundance and for the first appearance of the crystals showed that they decreased in the order of the following locations: Taproot; bundles, and surrounding tissues near where the taproot merges into the thickened root; inside the cambium in the more active xylem tubes and surrounding parenchyma; outside of the cambium layer in the cortex; medullary rays, decreasing inward; and, finally, only traces in the pith and leaf petioles, from which it disappeared first upon again withholding phosphorus from the nutrient solution. The turnips which received maximum phosphorus nutrition increased to from 3 to 4 inches in diameter while growing in the solution.

It was noticed, while following the progressive decrease and increase of phosphorus directly precipitable by magnesium mixture that there was the opposite condition concerning the amount of starch. Simultaneous with an increase in the absorption of phosphorus it was observed that the leucoplasts containing the compound starch grains shrunk in size as the starch grains were corroded and dissolved, until finally when the maximum amount of phosphorus had been introduced into the nutrient solution, starch had practically all disappeared from the root tissues only to reappear when phosphorus was again withdrawn from the nutrient solution.

Similar observations have been made at this station (5) concerning starch, especially in potato vines growing with widely differing amounts of various nutrients, and it seems probable that a retardation in growth and in consequent carbohydrate requirement, owing to suboptimum nutrient conditions, tends toward an increased deposition of starch, although it is possible that the nutrients may serve as activators of amylases.

Examinations for precipitable phosphorus in the tissues of turnips grown under natural conditions in soil containing varying amounts of available phosphorus have been recorded previously (6). They furnished indications that the extent to which crystals were produced in the tissues upon treatment with magnesium mixture varied to a certain extent with the amount of available soil phosphorus.

Owing to the fact that the greater part of the phosphorus in turnips exists in the cell sap, the principal work now to be recorded deals with the soluble phosphorus. Some observations based upon the preliminary work have been made already in another connection (8).

[1] The principal features of the anatomical structure were found to be as follows: The taproot and, at the early stage, the thicker portion above it are diarch. As the plant develops the latter portion becomes collateral. The root portion finally consists of radial rows of bundles of vessels surrounded by fibrous, sharp-pointed cells between which the parenchymatous medullary rays are located. The remaining central area consists of thin-walled cells of irregular shape and size, which usually contain much starch and perform the functions of a storehouse. At the locality from which the leaves come the vascular xylem is limited to a narrow area surrounding a distinct pith which contains no differentiated vessels. This extreme upper part of the so-called turnip root must be considered as the stem and is differentiated by its voluminous pith from the enlarged and fleshy root portion with which it merges.

EXTRACTIONS OF THE FRESH PULP

To determine in fresh turnips the proportion of the total phosphorus which is present in solution, the following method was used: Trimmed and cleaned fresh turnips were weighed and halved. Wedge-shaped portions with the edges at the center were grated off and the remainder of the turnips weighed, so that the amount of the grated portion could be determined by difference.

The amount of water and phosphorus was determined in the ungrated portion and the following average procedure was also carried out: Two hundred gms. of pulp were taken, 80 c. c. of water added in transferring the pulp and juice from the grater to the receptacle in which all was allowed to remain for about 24 hours, with occasional stirring, 230 c. c. of extract were obtained by filtering under pressure. Fifteen samples taken from a given field at eight different times during a growing season yielded on an average, in the trimmed fresh turnips, 91.4 per cent of water and 0.107 per cent of phosphorus pentoxid, 80 per cent of the latter being present in the liquid portion. In the determination of the amount of phosphorus in solution it was assumed that the liquid remaining in connection with the pulp after filtering, contained the same percentage of phosphorus as the filtrate. It was found that when the extraction was made by 0.2 per cent hydrochloric acid less total phosphorus was extracted than when water was used, and furthermore that some analytical difficulty was experienced in this connection, especially with subsequent determinations involving ammonia, owing to the presence of pectin-like substances. Previous extraction of the fresh pulp with alcohol did not prevent 0.2 per cent hydrochloric acid from extracting the pectin-like substances from the pulp.

A 2 per cent acidity produced by acetic acid did not result in the same difficulties with the pectin substances; therefore the hydrochloric extraction of the pulp was abandoned. The following percentages of phosphorus pentoxid calculated to dry turnips show that when fresh turnips are grated without and with the acetic acid considerably less phosphorus is secured in the solution when the acetic acid is present.

Sample.	I	II	III	IV	V	VI	VII
Without acetic acid.....	0.54	0.76	0.38	0.54	0.33	0.37	0.13
With acetic acid.....	.22	.61	.31	.52	.26	.26	.06

It seemed to be immaterial whether the 2 per cent acidity was attained by adding acetic acid at the time of grating or to the turnip juice subsequently, for in different samples 0.260, 0.063, and 0.025 per cent were obtained in the filtered juice when the acetic acid was present at the time of grating, and 0.259, 0.055, and 0.026, respectively, when added to the juice itself before filtering—that is, the addition of acetic acid to the juice produced a precipitate which contained about the same amount of phosphorus as was left with the pulp when acetic acid was in contact with the same at the time of grating.

DIALYSIS OF THE EXTRACTS

A number of measurements were obtained of the proportion of the total phosphorus in turnip extract, which failed to pass through dialyzers. In different experiments the dialysis was carried out in the presence of an acidity of 0.2 per cent hydrochloric acid, or 2 per cent acetic acid, or in an aqueous solution. Thymol or chloroform was used to prevent the growth of microorganisms. For a membrane parchment paper, pig's bladder, or chicken's crop was used. In some cases the diffusate was replaced repeatedly with the fresh solvent until diffusion had practically ceased, and the amount of phosphorus was then determined directly in the dialyzate. Again, when fewer replacements were made, time was allowed for equilibrium to be reached, and a deduction was made from the phosphorus in the dialyzate of the amount in an equal volume of the diffusate, the remainder being considered as colloidal phosphorus.

In the various experiments there was always less than 10 per cent of the phosphorus which seemed incapable of passing through a dialyzer; and when the diffusates were replaced many times by fresh solutions and a long time was allowed for the final diffusions, all but a few per cent of the phosphorus passed through the membrane.

If it be considered that dialysis separates crystalloidal from colloidal phosphorus, it is evident that there is not much of the latter in turnip juice. It should be said, however, that enzymolysis may have taken place, and of course the possibility of hydrolytic changes caused by the solvents should also be recognized.

Frequently, as will appear later, the main object in dialyzing the turnip extract was to obtain the dialyzates for the purpose of adding them to standard phosphate solutions, that an attempt might be made to find an analytical method which would completely recover as inorganic phosphorus that which was added in a standard solution.

In one sample, calculated on the basis of air-dried turnips, there was in the aqueous extract 43.4 per cent of solids and in the diffusates from the same through parchment paper 36.7 per cent; similarly, in the case of 0.2 per cent hydrochloric acid, the percentages were 50.3 and 40.2, respectively. The crude ash in the aqueous extract amounted to 7.6 per cent and, in the diffusates from the same, 6.7 per cent; whereas in the hydrochloric acid solution the percentages were 10.1 and 9.8, respectively.

DIRECT PRECIPITATION FROM THE EXTRACTS BY VARIOUS PRECIPITANTS OF INORGANIC PHOSPHORUS

When it was found that a large part of the phosphorus in turnips was in the water or acid extract, it seemed probable that at least under certain nutrient conditions much of it might not have undergone metabolism and thereby entered into combination with organic matter, but

might still be considered as inorganic phosphorus which would combine readily with the usual precipitants of the same.

Realizing the indefiniteness of so-called inorganic phosphorus in such circumstances, the authors did not attempt to determine definitely the nature of the phosphorus precipitable by different reagents, because the main object was to find methods for determining differences in composition in turnips grown on soils containing different amounts of available phosphorus. In general the designation "inorganic phosphorus" has been used in the present paper more for convenience than because it is necessarily considered as representing a well-defined entity.

It was found that the Hart and Andrews method (2), as outlined for use with cereals, required with turnip extract so much nitric acid to prevent reduction in the molybdenum mixture and to enable a complete recovery of added phosphorus that the official strength of nitric acid was adopted in most cases with this reagent.

Many direct precipitations were made also with the official magnesium mixture. The comparative amounts of that portion of the phosphorus which was precipitated directly by the magnesium and by the molybdenum mixtures, from different lots of turnip juice, are shown by the following: If the amount precipitated with the magnesium mixture in each case is represented by 100, the amounts thrown down by the molybdenum mixture were 100, 93, 99, 95, 102, 95, and 98; average, 97. The two mixtures therefore gave practically the same results. The precipitates caused by the two reagents were so treated that the total phosphorus in them was determined.

Barium chlorid in neutral solutions was also used extensively as a precipitant; in fact, it was finally adopted as being in general the most suitable reagent.

The best criterion of the efficiency of the different methods for precipitating inorganic phosphorus in the presence of the colloidal organic constituents of turnip extract was considered to be the degree of recovery of phosphorus added in a standard solution to the dialyzates of the turnip extracts, from which practically all the phosphorus had diffused.

Evidence presented in regard to the correctness of a given method for determining inorganic phosphorus is of questionable value if it is based upon the extent to which phosphorus added in a standard solution is recovered from an extract in which inorganic phosphorus had been determined previously by the same method.

At first there was failure by any of the precipitants to precipitate completely the phosphorus added to the dialyzate, but as barium chlorid seemed the most promising the conditions for practically complete recovery were ascertained finally with this reagent. It was not determined whether or not conditions could have been imposed in connection with the molybdenum and magnesium mixtures which would lead to a

complete recovery of added phosphorus, but such seemed probable from the results of the limited attempts which were made.

In preliminary work with undialyzed turnip juice and a standard phosphate solution containing phosphorus equivalent to 0.0200 gm. of magnesium pyrophosphate, there was obtained by barium chlorid from a neutral solution in 4, 8, 16, 24, and 72 hours, respectively, 0.0120, 0.0186, 0.0194, 0.0200, and 0.0200 gm. more than was secured from the juice alone. This indicated that 24 hours was sufficient time for complete precipitation. It was also ascertained that a large excess of the reagent was of no advantage.

Based upon this preliminary work, added phosphorus was recovered completely a number of times from dialyzates of turnip juice from which practically all of the phosphorus had diffused. However, owing to the fact that in a few instances thare was failure to recover all of the added phosphorus, it seems probable that a minus error is liable to occur when precipitating with barium chlorid from a strictly neutral solution, and it is probable that the method is more dependable if the solution is made slightly alkaline with ammonium hydroxid. A more detailed discussion of the method will occur in subsequent pages.

A limited amount of work was done with promising results by the method outlined by Collison (1), but the barium-chlorid method seemed well adapted for the work with turnip juice and was therefore mainly used.

ACTION OF OTHER REAGENTS AND CHANGES EFFECTED IN DIFFERENT WAYS

Although primarily interested in the determination of so-called inorganic phosphorus, the authors made certain examinations of turnip extract to ascertain the behavior of the phosphorus under different conditions, and these will be referred to briefly at this time.

Turnip juice is not of constant composition, but as an average less than one-tenth of the phosphorus in it is precipitated by acetic acid, more than seven-tenths by barium chlorid subsequently in the neutralized filtrate, and about two-tenths remain in the filtrate from the barium-chlorid precipitate.

The following data throw light upon the nature of the acetic-acid precipitate: Acetic acid was added to 1,500 c. c. of fresh juice until the acidity equalled 2 per cent; the mixture was allowed to stand for four days and was then filtered. The precipitate, after washing with 2 per cent acetic acid, was digested in a beaker for one hour at 37° C., with a solution of sodium hydroxid containing 0.5 per cent of free alkali. No reaction for inorganic phosphorus was secured when molybdenum mixture was added to the solution, thereby indicating that the phosphorus of the acetic-acid precipitate was not in compounds of a phosphoprotein nature (10). The alkaline digestion, however, so changed the acetic-

acid precipitate that only two-thirds of its original phosphorus could be subsequently precipitated in a 2 per cent acetic-acid solution, the remainder passing into the filtrate but still not reacting as inorganic phosphorus. The two-thirds of the phosphorus mentioned above as being reprecipitated with acetic acid were subsequently again dissolved in 0.5 per cent sodium hydroxid and reprecipitated with acetic acid without any further change in the amount of phosphorus in the acetic-acid precipitate. The reprecipitated and washed material contained about 13 parts of nitrogen to 1 part of phosphorus.

An examination for phytin in turnip juice was made as follows: Two 400-c. c. lots of turnip juice, each containing phosphorus equivalent to 0.2272 gm. of magnesium pyrophosphate, were treated with enough acetic acid to make a 2 per cent solution. A precipitate containing 3 per cent of the total phosphorus was formed. The filtrate was examined for phosphorus in phytin according to the following method of Posternak (11): The solutions were made strongly alkaline with sodium hydroxid, and calcium chlorid was added. The white precipitate was filtered off and the filtrate found to contain only a trace of phosphorus. The precipitate was dissolved in hydrochloric acid, and sodium acetate and copper acetate were added. Phytin was found to be practically absent (3, p. 440).

By heating turnip juice, variable small amounts of phosphorus are thrown down with the not very voluminous precipitate which is formed. The filtrate may at once yield more or less inorganic phosphorus than an unheated aliquot. After the lapse of a week or more, chloroform having been added to the solutions, there was invariably an increase of inorganic phosphorus in the unheated juice and usually no increase in the heated juice. This indicated the possible presence of an enzym capable of increasing the amount of inorganic phosphorus, but efforts to prove that there was enzymic action were not universally successful. The amount of inorganic phosphorus precipitated by the immediate addition of the customary reagents to the juice usually constitutes so large a proportion of the total phosphorus that there is very little opportunity for further change.

PROPORTION OF INORGANIC PHOSPHORUS

The principle method which was used by the authors in the determination of the inorganic phosphorus in fresh turnips has been published elsewhere (6). It consists in brief in preparing the pulp in the presence of sufficient acetic acid to give about a 2 per cent acid extract, to which barium chlorid is then added as a precipitant, the solution being rendered neutral or barely alkaline with ammonium hydroxid. The inorganic phosphate is dissolved on the filter from the precipitate by treatment with hot water and acid, and the phosphorus brought into solution is determined in the usual manner with molybdenum and magnesium mixtures.

At first indications were afforded by this method that a larger proportion of the total phosphorus was secured from turnips grown on soil well supplied with available phosphorus than from turnips which had been grown on soil quite deficient in this ingredient. This was considered to be an important differentiation regardless of whether or not the determination could be considered strictly that of inorganic phosphorus, since it appeared to furnish an additional indirect method for securing information regarding the relative amount of available phosphorus at the disposal of the plant.

However, according to subsequent work with the method by other analysts on turnips grown in a number of different years, there were frequent failures to find any marked increase in the proportion of inorganic to total phosphorus in the turnips as a result of the application to the soil of liberal amounts of available phosphorus, although the crop and the percentage of total phosphorus in the same were much increased.

It was found in some instances that a small excess of ammonium hydroxid resulted in a considerable increase of inorganic phosphorus in the precipitate by barium chlorid. There was no certainty as to whether this increase represented a portion of the inorganic phosphorus not precipitable from a neutral solution, or whether the excess ammonia had caused a dissociation of phosphorus from organic combinations. By adding an excess of ammonia, on the assumption that all of the inorganic phosphorus was not precipitable in a neutral solution, practically the total phosphorus was frequently precipitated.

It has already been shown that phytin was absent from the juice, and it may well be questioned whether the small amount of phosphorus usually contained in the rather voluminous precipitate formed upon the addition of alcohol to the acidulated juice is an essential constituent of the same or has merely been dragged down by it.

If it is true that nearly all the phosphorus of the juice is inorganic, as seems likely to be the case, at most only the determination of total phosphorus in the juice could be of advantage for the purpose in mind; furthermore the determination of total phosphorus in the juice would be no more useful than that in the entire turnip unless differences in the amount of available soil phosphorus influence the composition of the juice more than of the rest of the turnip.

Such an influence seemed reasonable, and some evidence for that idea has been secured. At other times, however, an increase in the amount of available soil phosphorus seems to have increased the phosphorus of the juice no more than of the rest of the turnip.

Looking upon the inorganic phosphorus in the juice as being the excess above that required for the essential tissues, one would hardly expect to find much phosphorus in this form in turnips which had made only a small growth because insufficient soil phosphorus was available. Possibly, however, the turnip conserves a certain proportion of inorganic

phosphorus in its thickened root, even if the supply is insufficient to produce a full-sized plant. Inasmuch as the second year of this biennial is devoted to the production of seed, using as nourishment the root substance formed the previous year, a certain amount of inorganic phosphorus may be a normal requirement. Turnips which have been stored still contain a large proportion of such phosphorus, but the authors have not ascertained whether this phosphorus supplies the early needs of the second-year's growth.

As a result of a critical consideration of all the data, the authors feel that the determination of the total phosphorus in turnips may prove as satisfactory for indicating the relative amount of available phosphorus in the soil upon which the turnips grew, as a determination of inorganic phosphorus in the juice by any method which they have tried, although in many instances the differences are more marked by the latter determination.

SUMMARY

In this paper is recorded work undertaken with the prime object of ascertaining whether the amount of any portion of the phosphorus of the turnip root is correlated more nearly than the total phosphorus with the relative amount available in soils.

Preliminary indications were derived from the successive extraction of dried turnips with ether, alcohol, and 0.2 per cent hydrochloric acid; but, since it was next found that larger amounts of phosphorus could be extracted from fresh than from dried turnips, all subsequent observations were made on fresh turnips.

Coincident with the introduction of phosphorus into a nutrient solution in which turnips were growing, the appearance of "inorganic" phosphorus and the disappearance of starch were traced microscopically in the different tissues; whereas upon withholding phosphorus the disappearance of inorganic phosphorus and the appearance of starch were similarly observed. About four-fifths of the total phosphorus of fresh turnips was extracted with water. When the latter was acidulated, somewhat less was secured because of partial precipitation.

Only a few per cent of the extracted phosphorus failed to pass through dialyzers. Different precipitants of inorganic phosphorus were tested as to their ability to recover phosphate added in a standard solution to the dialyzates.

The phosphorus in the precipitate formed by adding acetic acid to turnip juice was not in phosphoprotein compounds. There was no phytin in the juice. The presence of a phosphatase was not shown.

Although the proportion of inorganic to total phosphorus in turnips was frequently made larger by phosphatic applications to the soil in which they were grown, this was not always shown to be the case by such methods as were used.

In most instances the phosphorus in the juice was so largely inorganic and constituted so large a proportion of the total that the determination of the latter seemed about as useful as of any portion for furnishing indications regarding the relative amount of soil phosphorus at the disposal of the turnip.

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THREE-LINED FIG-TREE BORER

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INTRODUCTION

The adult three-lined fig-tree borer (*Ptychodes trilineatus* L.) is a large, longitudinally striped, long-horned, wood-boring beetle of the family Cerambycidae, which does considerable damage to fig trees (*Ficus carica*) in the Southern States by boring into the larger branches and trunks.[1]

This insect occurs throughout the southern United States from Florida to Houston, Texas, and from South Carolina to the Gulf. It has also been reported from parts of Mexico, British Honduras, Nicaragua, Costa Rica, Guatemala, Panama, and the West Indies, Colombia, and Venezuela, South America, and Tahiti, Oceania. The adult beetle causes some injury by feeding upon the fruit, leaves, and bark of fig trees and by ovipositing in the bark, but the greatest amount of damage is done by this insect while in the larval state. The larva is a white, flat-headed borer, or sawyer, which mines its way into the larger branches and trunks of the trees (Pl. 37), where it feeds upon the wood for from three months to more than one year, and reaches a length of nearly 2 inches, before changing to the pupa.

INJURIOUSNESS

The borers live in dry as well as in green wood, and specimens have lived for two or three weeks in other woods than the fig. Two larvæ from one lot under observation ate their way out of their blocks of fig wood and into the top of a cypress table, where they tunneled for 2 and 3 inches, respectively, and completed the transformation to the adult stage. They appear to prefer wood which is partly dead and has lost some of its sap to healthy green wood, and therefore attack principally those trees or branches which are injured or diseased. Any injury, however, such as the breaking of a large limb, may invite the deposition of many eggs by the adult beetle, and the branch will then be killed by the borers. The first attack will, furthermore, generally be followed by others until the whole tree becomes involved and is finally killed by the insect.

Favorite points of attack are near wounds made by the breaking of large limbs, untreated saw cuts, splitting of the trunk, the knots formed

[1] Several other borers also attack fig trees in the Southern States—for example, *Leptostylus biustus* Lec., *Goes* sp., *Stephanoderes* sp., and *Ataxia crypta* Say—and are found working in the same trees with *Ptychodes trilineatus*.

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in the branches by fig canker,[1] injuries in the bark, etc. For example, a fig tree on the laboratory grounds at New Orleans, which through faulty pruning a comparatively light wind had caused to split down through the head, became so severely infested that it was estimated there were more than 1,700 borers in it at one time. Another fig tree which had been perfectly healthy and free from borers became severely infested in the trunk soon after the bark had been injured by a mercurial band applied to keep out ants. Still another healthy tree first became infested after a windstorm had broken off one of the larger branches, the eggs all being deposited in the branch from which it was broken, not far from the wound.

Every one of the six or eight injured or diseased fig trees on the laboratory grounds at New Orleans became heavily infested with borers, whereas not a single egg or borer could be found during three seasons in any of the 8 or 10 well-formed, healthy trees growing near them in the same yard. It may therefore be set down as a practically infallible rule that if the fig trees are kept in a thriving healthy condition, they will not be subjected to severe attacks, and may escape any injury whatever from the three-lined fig-tree borer.

BIOLOGY AND HABITS

THE EGG

DESCRIPTION AND PLACE WHERE FOUND

The egg (Pl. 35, A) is an elongate, nearly cylindrical, pure white to faintly yellowish or greenish object, ranging from 0.026 inch (0.66 mm.) to 0.039 inch (1 mm.) broad, from 0.128 inch (3.25 mm.) to 0.144 inch (3.66 mm.) long, being on an average 0.036 inch (0.916 mm.) broad and 0.138 inch (3.52 mm.) long. The shell is often more or less distinctly patterned like the grain of the fig wood in which the egg is deposited.

The eggs are deposited by insertion into the bark of the larger branches and trunk, thus being completely hidden from view and protected by the bark. They are usually deposited near wounds or decaying spots in the bark, or in limbs which have been cut or broken. They are even deposited in large branches which have been removed from the tree. They are seldom or never found in perfectly sound, healthy bark, a fact of importance in controlling the borer. The eggs usually occur singly, but sometimes two, three, or five are found together.

INCUBATION

The incubation period of eggs of the fig-tree borer does not vary greatly, at least in the period from May to September, when most eggs are developing. The maximum time required for the eggs to develop, as recorded in the season of 1914 and 1915, was 8 days, the minimum 3 days, the

[1] EDGERTON, C. W. DISEASES OF THE FIG TREE AND FRUIT. La. Agr. Exp. Sta. Bul. 126, p. 10-12, pl. 5. 1911.

average being approximately 5.6 days. The comparative regularity of the time required for incubation appears to be due to the relative uniformity of temperature and humidity prevailing in the bark tissues of the fig trees. The complete record on the incubation of eggs of the fig-tree borer at New Orleans, La., for the seasons of 1914 and 1915 is given in Table I.

TABLE I.—*Incubation period of eggs of the three-lined fig-tree borer, New Orleans, La., 1914 and 1915*

Number of eggs in the record.	Date of deposition.	Date of hatching.	Incubation time.	Number of eggs in the record.	Date of deposition.	Date of hatching.	Incubation time.
	1914.	1914.	*Days.*		1915.	1915.	*Days.*
9	July 2	July 5	3	2	June 1	June 7	6
17	July 4	July 9	5	2	...do	June 8	7
5	...do	July 11	7	1	June 2	June 7	5
6	July 27	Aug. 1	5	3	...do	June 6	4
9	July 28	Aug. 3	6	1	...do	June 8	6
6	July 31	Aug. 4	4	3	June 3	...do	5
2	...do	Aug. 5	5	4	June 7	June 11	4
4	...do	Aug. 6	6	5	...do	June 12	5
1	...do	Aug. 8	8	7	...do	June 13	6
6	Aug. 1	Aug. 5	4	8	June 9	...do	4
1	...do	Aug. 6	5	10	June 11	June 16	5
7	Aug. 3	Aug. 7	4	2	...do	June 18	7
1	...do	Aug. 8	5	3	June 12	June 15	3
7	Aug. 11	Aug. 14	3	7	...do	June 18	6
1	...do	Aug. 16	5	11	June 14	...do	4
				6	June 15	June 20	5
	1915.	1915.		13	June 18	June 23	5
9	May 24	May 31	7	2	...do	June 25	7
1	...do	June 1	8	5	June 20	...do	5
1	May 25	June 2	8	7	June 26	June 30	4
8	May 26	June 1	6				
1	...do	June 2	7	210			
3	May 29	June 5	7		Maximum		8
1	May 30	June 6	7		Minimum		3
2	...do	June 5	6		Average		5.6

HATCHING

When the development of the egg is completed and the larva ready to issue it chews its way out through the upper end of the eggshell. The larvæ generally feed at first upon the eggshell, sometimes devouring nearly all of it before tunneling into the bark layers.

LARVA OR BORER

DESCRIPTION

The larva, or borer proper (Pl. 35, B, C), is white to cream-colored, a legless grub, varying in length from about 0.125 inch (3 mm.) just after issuance from the egg to about 1.7 inches (43 mm.) when fully grown. It is broadest across the first thoracic segment, tapering gradually from the latter to the tip of the abdomen. The head is subrectangular, its sides converging posteriorly. The anterior border has a small 4-jointed appendage at each side of the base of the mandible. The anterior

border and mandibles are dark brown to nearly black, and the posterior part of the head clear light amber. The anterior and lateral borders of the first body segment are of a shining, yellowish brown, and the posterior half velvety-brown; the remaining segments are creamy-white throughout. The dorsal and ventral surfaces of abdominal segments are tuberculate, the minute dorsal tubercles being arranged in four irregular rows, forming two irregular oval rings, one within the other. The last segment bears on its ventral surface a small group of amber-colored, chitinous spines.

Mr. F. C. Craighead, of the Bureau of Entomology, who has especially studied the classification of the larvæ of the Cerambycidae, gives the following characters for distinguishing the larvæ of *Ptychodes trilineatus* from others of that family:

> Sides of head converging posteriorly; dorsal surface of prothorax vellured on posterior half; dorsal and ventral surfaces of abdominal segments tuberculate, tubercles on dorsal surface arranged in four irregular rows.

These characters will distinguish larvæ of the subfamily Lamiinae, to which *Ptychodes trilineatus* belongs, from those of the other subfamilies. The presence of a small group of chitinous spines, on the ventral surface of the last abdominal segment, distinguishes the larva of the three-lined fig-tree borer from that of other species of the genus Ptychodes.

MOLTING AND GROWTH

The number of instars, or substages in the growth of the larva of the three-lined fig-tree borer, is variable and the occurrence of the molts irrregular. A little more than half the specimens under observation molted only five or six times before transforming to the pupa, about one-fourth of them made the transformation after the eighth molt, and the remaining fourth after the fourth, seventh, ninth, or tenth molts. It is only rarely that as many as 10 molts occur in the larva. The insect will sometimes molt twice in close succession after being cut or otherwise injured, the extra molting being apparently a protective measure in such cases. In molting, the head cast splits slightly along the median ventral line, separates from the body integument, and is slipped off whole. The skin is slowly pushed back over the tip of the abdomen.

There is also a wide variation in the duration of the larval instars. Each of the first three instars may be completed in anywhere from 3 days to about 40 days, while each of the succeeding ones requires from about one week, as a minimum, to between 50 to 60 days, as a maximum, for those specimens which complete their growth in a single summer. With larvæ which live through the winter from one season to the next, the later stages of growth will be much longer, requiring 5 or 6 months. The average duration of the different substages in the growth of the larva was as follows: Instar I, 8 days; II, 9 days; III, 12 days; IV, 16 days; V, 23 days; VI, 26 days; VII, 38 days for those specimens not passing and 5 months for those passing the winter in the larval stage;

VIII, 34 days for specimens completing their growth during the same summer in which they issued, and 6½ months for larvæ living over the winter; IX, 30 days for summer specimens, and 5½ months for those living through the winter as larvæ.

LENGTH OF LIFE AND HABITS

When the young borer issues from the egg, it mines its way along through the bark for several days. It then usually tunnels into the solid wood and often eats its way to the very heart of the branch. It lives and feeds in this manner, packing the burrow tightly behind it with "sawdust," for from about 2 to 15 months. About two-thirds of the borers observed completed this stage in the season in which the eggs from which they issued were deposited, while the remaining third lived through the winter, pupating the following season. Those borers completing the larval life in one season required approximately from 2 to 4½ months, the average larval life of the single season specimens being about 3 months. The overwintering borers required from 7½ to 15 months to complete the larval life, the average life in the wood being 11⅓ months. As the borers are feeding during most of this long period, and reach a size of 1.5 to 2 inches long and nearly 0.25 inch broad, it is seen that even a single insect can cause a great deal of injury. The records on the duration of the larval stage are given in Table II.

TABLE II.—*Duration of the larval stage of the three-lined fig-tree borer, New Orleans, La., 1915–16*

No.	Date of issuance.	Date of pupation.	Duration of larval stage.	No.	Date of issuance.	Date of pupation.	Duration of larval stage.
			Months.				*Months.*
1	May 21, 1915	Sept. 29, 1915	4.33	37	June 18, 1915	Sept. 7, 1915	2.75
2	do	Aug. 28, 1916	15	38	do	Sept. 18, 1915	3
3	June 1, 1915	Mar. 31, 1916	10	39	do	Sept. 7, 1915	2.75
4	June 2, 1915	Oct. 9, 1915	4.25	40	do	Sept. 29, 1915	3.5
5	June 1, 1915	Aug. 27, 1915	3	41	do	do	3.5
6	June 5, 1915	Sept. 29, 1915	4	42	do	Aug. 28, 1916	12
7	do	July 10, 1916	13	43	do	Aug. 31, 1915	2.5
8	June 7, 1915	Sept. 7, 1915	3	44	do	May 15, 1916	11
9	June 8, 1915	July 10, 1916	13	45	do	Mar. 31, 1916	9.5
10	June 7, 1915	Sept. 29, 1915	3.5	46	do	Sept. 18, 1915	3
11	June 6, 1915	Aug. 27, 1915	2.66	47	do	Aug. 31, 1915	2.5
12	June 8, 1915	Sept. 7, 1915	3	48	June 20, 1915	Mar. 31, 1916	9.5
13	do	Sept. 13, 1915	3.25	49	do	Sept. 18, 1915	3
14	June 11, 1915	Sept. 7, 1915	3	50	do	Mar. 10, 1916	8.6
15	do	Mar. 31, 1916	9.5	51	June 23, 1915	Oct. 9, 1915	3.5
16	do	do	9.5	52	do	Aug. 28, 1916	14
17	June 12, 1915	Aug. 27, 1915	2.25	53	do	Oct. 16, 1915	4
18	do	Aug. 28, 1916	14.5	54	do	Sept. 7, 1915	2.5
19	do	Aug. 17, 1915	2.25	55	do	Sept. 18, 1915	3
20	June 11, 1915	Aug. 27, 1915	2.5	56	do	Oct. 16, 1915	4
21	do	Sept. 18, 1915	3.25	57	do	June 12, 1916	11.6
22	do	Aug. 27, 1915	2.5	58	do	Oct. 9, 1915	3.5
23	June 13, 1915	Mar. 31, 1916	9.5	59	do	do	3.5
24	do	Aug. 27, 1915	2.5	60	June 25, 1915	Aug. 19, 1915	1.8
25	do	do	2.5	61	do	Sept. 29, 1915	3.25
26	do	Aug. 28, 1916	14.5	62	June 30, 1915	do	3
27	do	Aug. 27, 1915	2.5	63	do	Oct. 16, 1915	3.5
28	do	Oct. 25, 1915	4.5	64	do	Feb. 17, 1916	7.5
29	do	May 15, 1916	11	65	do	Sept. 29, 1915	3
30	June 16, 1915	Sept. 18, 1915	3.25	66	do	Aug. 31, 1915	2
31	do	Sept. 29, 1915	3.5	67	July 2, 1915	Mar. 31, 1916	9
32	do	May 15, 1916	11				
33	do	Aug. 19, 1915	2		Maximum		15
34	do	Aug. 28, 1916	14.5		Minimum		1.8
35	June 15, 1915	Aug. 19, 1915	2.25		Average		5.6
36	do	Sept. 7, 1915	2.75				

When the larva is ready for pupation, it tunnels its way to a point near the surface, enlarges the cavity slightly, and completely surrounds itself with a sort of cell, or cocoon, composed of shreds and pellets of wood, tightly glued together. After making the cocoon, the larva ceases feeding, shrinks slightly, and molts, transforming to the pupal stage.

RESISTANCE OF THE LARVA TO INJURIES

While the larva of the three-lined fig-tree borer is soft bodied, and easily injured when removed from the protecting fig wood, its resistance to knife cuts and similar mechanical injury is great, as specimens cut so severely as to cause the loss of a considerable quantity of body fluid will often entirely recover and complete their development. Thus, one specimen which was cut nearly in two and had lost much of the body fluid recovered and reached the adult stage in the usual time, as did several others with injuries only slightly less severe. On one occasion, when a large-sized borer was chewed nearly in two and lost one of its mandibles as the result of meeting another borer in the wood, both wounds completely healed and the insect survived for more than a month. During this time the body cavity was closed by a thin, transparent membrane. The borer was, of course, unable to feed. A glossy black scab usually forms over a cut or abrasion in the larval skin. Infections often occur through abrasions, and this was the principal cause of the loss of injured specimens in the rearing work.

THE PUPA

DESCRIPTION

The pupa (Pl. 35, D, E) on first emerging is creamy-white, but soon takes on more yellow and develops a brown shading on the feet, the tips of the antennæ, and the mouth parts. As development progresses the eyes and mandibles turn amber-brown, then the prothorax, head, antennæ, sides of abdomen, and tips of wings take on similar coloring. The size varies slightly in the sexes and in different specimens of the same sex. The length ranges from approximately 0.78 to 1.06 inches (20 to 27 mm.), with an average of approximately 0.94 inch (24.06 mm.); the breadth of the thorax from approximately 0.19 to 0.23 inch (5 to 6 mm.), with an average of approximately 0.21 inch (5.5 mm.); that of the abdomen from about 0.22 to 0.29 inch (5.75 to 7.50 mm.), with an average of approximately 0.23 inch (6.5 mm.). The antennæ are 11-jointed but, owing to the fusion of the second and third joints, there appear to be only 10. They are directed backward along the sides of the body, the last seven joints resting curled together against the wing. The wings extend backward and downward under the abdomen, their tips reaching almost to the hind margin of the second abdominal segment. On each side of the dorsum of the prothorax are 16 small brown setæ or hairs arranged as follows: 1 long hair near the middorsal line near the front margin, 2 loose patches of 5 smaller hairs on the middle portion of each half of the prono-

tum, the rear patch being opposite its lateral marginal projection, the remaining 5 hairs set irregularly along the middorsal line and the hind margin of the pronotum. On the mesonotum are about 25 similar hairs so arranged as to form a V, the point directed toward the tip of the abdomen. A similar but larger V occurs on the mesothorax. On the dorsum of the first two abdominal segments is a thick brush of minute brown hairs, divided in the middle by the median dorsal line, consisting of the following numbers of hairs: On segment 3, about 44; segment 4, about 22; segment 5, about 19; segment 6, about 16; and segment 7, about 10. A group of similar setæ occurs at the base of each antenna and on the labrum and clypeus.

The life of the pupa is passed entirely within the sawdust cell constructed by the borer in its tunnel in the wood. When the pupal skin has been cast and the newly formed adult has hardened somewhat, it chews a circular hole through the bark and emerges into the outer air. The exit holes of the adult beetle are almost perfectly circular, and the occurrence of such holes in trunk and limbs indicates the escape of adults, not the entrance of larvæ.

DURATION OF THE PUPAL STAGE

The duration of the pupal stage, like that of the larval stage, is quite irregular. The extreme minimum duration in the specimens under observation was 5 days, but this occurred only in two cases. The extreme maximum was 73 days. The average duration of the pupal stage for all of the 70 specimens observed through that stage was 24 days. The complete records on the duration of the pupal stage are given in Table III.

TABLE III.—*Duration of the pupal stage of the three-lined fig-tree borer, New Orleans, La., 1914, 1915, and 1916*

No.	Date of pupation.	Date of emergence.	Duration of pupal stage.	No.	Date of pupation.	Date of emergence.	Duration of pupal stage.
	1914.	1914.	*Days.*		1915.	1915.	*Days.*
1	Sept. 1	Sept. 15	14	16	Aug. 17	Sept. 6	20
2	...do....	Sept. 22	21	17	...do....	Aug. 31	14
3	...do....	Sept. 14	13	18	Aug. 19	...do....	12
4	...do....	Sept. 22	21	19	...do....	...do....	12
5	...do....	Sept. 15	14	20	Aug. 27	Sept. 13	17
6	Sept. 9	Sept. 29	20	21	...do....	...do....	17
7	...do....	Sept. 22	13	22	...do....	...do....	17
8	...do....	...do....	13	23	...do....	...do....	17
9	...do....	Sept. 15	6	24	...do....	...do....	17
10	...do....	Sept. 22	13	25	...do....	Sept. 16	20
11	Sept. 29	Oct. 16	17	26	Aug. 31	...do....	16
	1915.	1915.		27	...do....	Sept. 12	12
12	Apr. 24	May 15	21	28	...do....	...do....	12
13	May 25	June 5	11	29	Sept. 7	Sept. 16	9
14	May 28	June 16	19	30	...do....	Sept. 18	11
15	Aug. 17	Sept. 6	20	31	...do....	...do....	11
				32	...do....	...do....	11

TABLE III.—*Duration of the pupal stage of the three-lined fig-tree borer, New Orleans, La., 1914, 1915, and 1916*—Continued

No.	Date of pupation.	Date of emergence.	Duration of pupal stage.	No.	Date of pupation.	Date of emergence.	Duration of pupal stage.
	1915.	1915.	*Days.*		1915.	1915.	*Days.*
33	Sept. 7	Sept. 18	11	53	Oct. 16	Nov. 8	23
34	...do	...do	11	54	...do	...do	23
35	...do	...do	11	55	...do	Nov. 12	27
36	Sept. 18	Sept. 30	12	56	Oct. 25	Nov. 15	21
37	...do	...do	12				
38	...do	Sept. 23	5		1916.	1916.	
39	...do	...do	5	57	Feb. 17	Mar. 31	42
40	...do	Oct. 4	16	58	Mar. 10	May 16	67
41	...do	...do	16	59	Mar. 31	June 12	73
42	Sept. 29	Oct. 13	14	60	...do	...do	73
43	...do	Nov. 15	47	61	...do	...do	73
44	...do	Oct. 19	20	62	...do	...do	73
45	...do	Oct. 14	15	63	...do	...do	73
46	...do	Oct. 18	19	64	...do	May 15	45
47	...do	Oct. 16	17	65	...do	May 25	55
48	...do	Oct. 24	25	66	Apr. 16	May 15	29
49	...do	Oct. 18	19	67	May 15	July 10	56
50	Oct. 9	Oct. 27	18	68	...do	...do	56
51	...do	Nov. 1	23	69	July 10	July 26	16
52	...do	Nov. 3	25	70	...do	Aug. 28	49
	Maximum						73
	Minimum						5
	Average						24

THE ADULT

DESCRIPTION

The adult three-lined fig-tree borer (Pl. 36) is a long-horned beetle of the family Cerambycidae. The body is elongate, the females measuring from about 0.86 inch (22 mm.) to 1.1 inches (28 mm.) long from the vertex to the tip of the elytra, the average length being approximately 1 inch (25.5 mm.). The greatest width of the prothorax of the female is, on an average, about 0.2 inch (5.25 mm.), of the metathorax, across the base of the wing covers, about 0.27 inch (7 mm.).

The male varies from about 0.55 inch (14 mm.) to 0.82 inch (21 mm.) in length, being, on an average, about 0.75 inch (19.1 mm.) long. The prothorax is, on an average, about 0.16 inch (4.08 mm.), and the metathorax 0.21 inch (5.4 mm.) wide. The antennæ are 11-jointed, nearly 2½ times the length of the body (average 2.48 inches). The vertex is deeply and narrowly channeled, the channel extending in a distinct suture for the length of the head. The eyes are nearly divided, the lower lobe much broader than the upper. Prothorax cylindrical, narrowest in front. The legs are slender, the fore pair the longest. The body is broadest across base of the elytra, which taper toward their tips and end in a short sutural spine. The first and fifth ventral segments are longer than the intermediate ones. The general coloring of the dorsum,

owing to a dense covering of fine appressed hairs, is brown and white in longitudinal stripes. Two broad brown stripes, punctuated with minute orange tufts in longitudinal rows, extend from antennæ to the tips of the elytra. A median scalloped white to yellowish stripe extends the length of the dorsum, ending abruptly at the anterior margin of the prothorax, and two similar lateral stripes extend from near the tips of the elytra along their margins to the bases of the antennæ. The integument beneath the tomentum is a dark amber-brown, finely punctate. The surface color of the antennæ, legs, and underside of the body is dark gray to brown. When first emerged, the general color is a very light brown to cream-yellow, with very faint white stripes.

FOOD OF THE ADULT

The adult beetles feed upon the tender bark of the smaller fig stems, and in captivity, when fed with such stems with the leaves attached, have eaten freely of the leaves. During the fruiting season they also feed to a considerable extent upon ripe and nearly ripe figs. They have been kept in captivity for several months, by feeding them leaves, fruit, and bark of the fig tree.

DURATION OF ADULT LIFE

The longevity of the adult three-lined fig-tree borer as determined upon 24 specimens in 1914–15 ranged from a minimum of about 2.5 months (75 days) to about 7.25 months (222 days). About one-fourth of the specimens lived 3 months or slightly longer, and the average length of life of all was 3.7 months. The complete records are given in Table IV.

TABLE IV.—*Longevity of adults of the three-lined fig-tree borer, New Orleans, La., 1914–15*

Number of specimens.	Date of emergence.	Date of death.	Duration of adult life.	
	1914.	1914.	*Days.*	*Months.*
6	June 22	Sept. 5	75	2.5
2	...do....	Sept. 14	84	2.75
1	...do....	Nov. 2	133	4.33
5	...do....	Sept. 22	92	3
		1915		
3	...do....	Jan. 21	213	7
1	...do....	Jan. 30	222	7.25
1	Sept. 22	...do....	130	4.33
	1915.			
1	Apr. 23	July 31	99	3.25
1	...do....	Sept. 14	144	4.75
1	May 6	July 29	84	2.75
1	May 15	Sept. 14	122	4
1	May 6	Sept. 1	118	3.75
Total, 24.				
Maximum				7.25
Minimum				2.5
Average				3.75

OVIPOSITION

In ovipositing, the insect usually stands with the body parallel to the axis of the trunk or branch, with the head toward its upper extremity, and makes a double transverse incision in the bark with the mandibles. The ovipositor is then inserted into one of the incisions, and the egg thrust downward and into the bark to a depth of from 0.125 to 0.25 inch. As a rule a cut is made in the bark for every egg, but sometimes two or three, and rarely as many as five eggs are deposited side by side. The "egg bite," consisting of two small, transverse slits made side by side in the bark by the mandibles, is usually the only external evidence of the presence of eggs; but on rare occasions the eggs are inserted so near the surface as to be visible as slight elevations in the bark.

The preoviposition period, or the time elapsing between emergence and oviposition, ordinarily varied from 8 to 16 days; but in a few specimens it was nearly a month. Most of the specimens required 8 days. The females also lived from 8 to 26 days after they had ceased to deposit eggs, but this was in the fall and winter when cool weather probably retarded oviposition.

NUMBER OF EGGS DEPOSITED

A complete record of oviposition was obtained from nine insects in 1914 and 1915. Three of the specimens deposited approximately 101 eggs each at the average rate of 1.5 eggs each per day; three more specimens deposited approximately 184 eggs each at the average rate of 1 egg each per day, and a seventh insect deposited 110 eggs at the rate of 1.4 eggs per day. The remaining two females deposited approximately 261 eggs each at the average rate of 2.4 eggs each per day. The oviposition record is given in Table V.

TABLE V.—*Oviposition record of the three-lined fig-tree borer, New Orleans, La., 1914 and 1915*

Number of specimens.	Date of beginning oviposition.	Date of ending oviposition.	Number of days of oviposition	Number of eggs deposited.
	1914	1914		
3	June 30	Sept. 4	66	302
3	June 30	Dec. 26	179	553
	1915	1915		
2	May 22	Sept. 6	107	523
1	Sept. 29	Dec. 15	77	110

From the foregoing it is seen that a single female three-lined fig-tree borer will deposit from 100 to 184 eggs in the course of her life at an average rate of from 1 to 2.4 eggs per day.

SEASONAL HISTORY

Adult beetles of the three-lined fig-tree borer first begin to emerge in March, but it is not until May that emergence is well under way, with the beetles appearing rapidly. The largest number of beetles appear in September, and the last specimens emerge in November or early December. These late-emerging beetles will deposit eggs on the warmer days of winter till at least as late as January 24. Fewest eggs are deposited in the months from February to April, inclusive, and the greatest number from May to September, inclusive. There is no true hibernation period in the latitude of New Orleans, but there is a period of comparative inactivity during the months from December to February, inclusive, during which, however, a slight amount of oviposition occurs, and eggs, larvæ, pupæ, and adults may be found in the fig wood.

The life cycle, from egg to adult, was passed by 54 specimens, or about five-sixths of the number observed through all stages, in the same season in which the eggs were deposited, their average life cycle being 3.5 months. Ten, or about one-sixth of them, lived through from May to June of one year to May and June of the following year, their average life cycle being 11.5 months. The generations are irregular, the hatch of the eggs deposited in the months from March to May reaching the adult state in the months from June to November, the hatch of a majority of those deposited in June and July becoming adults in the months from August to November, inclusive, and the remainder from March to June of the following year.

CONTROL OF THE BORER

Since the adult three-lined fig-tree borer does not as a rule oviposit in the perfectly sound limbs or trunk of the healthy trees, the most important measure of control is to keep the trees in the healthiest condition possible. The larger branches, 1 inch in diameter and upward, and the trunk are the parts particularly susceptible to attack.

Care should be taken to avoid bruising the bark or breaking limbs in cultivating and in picking the fruit, and the trees should be shaped to strengthen them as far as possible against breaking or splitting by heavy winds. The work of such diseases of the limbs as fig-canker and fig-limb blight should also be prevented as far as possible.

When a branch is accidentally broken, it should be immediately cut off smooth at its juncture with the larger branch or trunk and the wound painted with a mixture of five parts of coal tar and one part of creosote. At least a second and possibly a third coat should be applied when the preceding coat is dry.

It is important to prevent the first branch of a tree from becoming infested, as one infested and dying branch will invite further attacks

upon the trees. When a branch has become infested, it should be removed and burned, as the borers will complete their development even in perfectly dead and dry wood and later infest other trees. Fig-wood prunings should always be destroyed, and never allowed to remain long in or near the orchard.

Freezing of the bark is likely to be followed by borer attack in the branches affected, and such branches should therefore be cut off and the surface of the cut painted as above recommended. When the bark becomes diseased or bruised, the affected area should be removed with a sharp knife, cutting square across to the sound wood, and coating with a protective paint so the bark will heal perfectly.

Trees already heavily infested with borers in the trunk, may as well be at once cut down and every scrap burned, as it will be practically impossible to save them and they will be a source of infestation and a menace to the healthier trees. Trees which are split through the head, those which are in a dying condition from any cause, and the volunteer trees which so persistently spring up from the roots of some varieties of older fig trees grown in southern Louisiana, should also be cut down and burned.

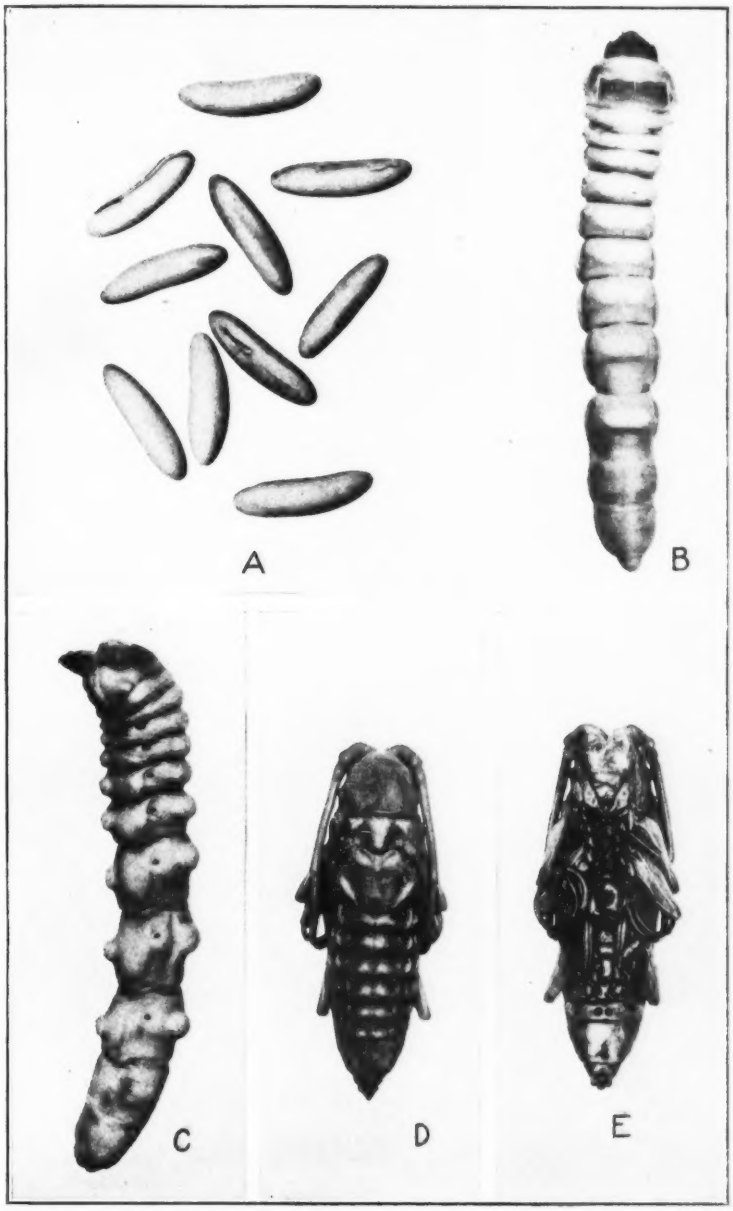
While it is best, where the infestation occurs only in certain branches, to remove the infested branches entire, the borers may be dug out of highly prized individual trees if the infestation has not progressed too far and its area is limited. Some good may also be accomplished, in such cases, by destroying the eggs with a knife or an awl. It would first be necessary, however, to become familiar with the appearance of the egg punctures and eggs. Yard trees should first of all, of course, be kept in a healthy condition in order to prevent attack by the borers. Oviposition may largely be prevented, in the case of a few yard trees, by insheathing the trunk and larger branches with wire netting. The screen would have to be kept in place practically throughout the year.

The borers in some cases may be killed by injecting carbon bisulphid into the tunnels and plugging the openings with putty, but this method is impracticable where the infestation is severe and well advanced.

PLATE 35

Ptychodes trilineatus: Immature stages

A.—Egg. ×8.
B, C.—Full-grown larva. ×2.
D, E.—Pupa. ×2.


A
B
C
D
E

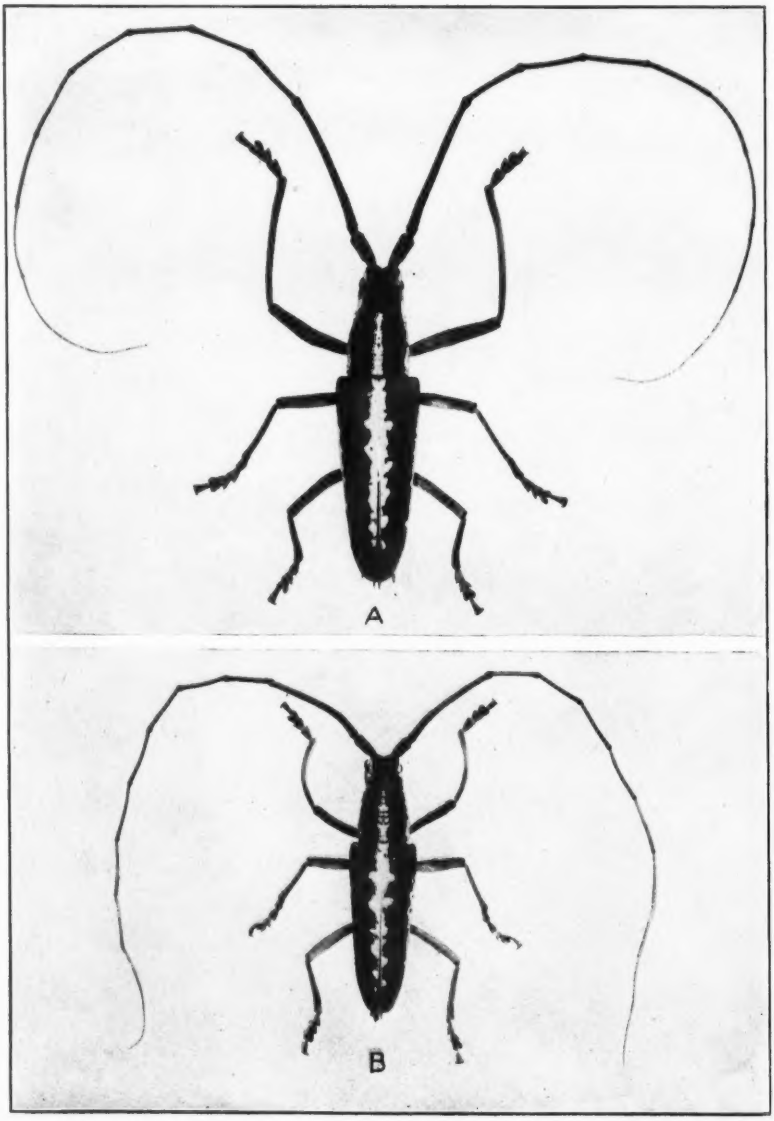

A
B

PLATE 36

Ptychodes trilineatus: Adult

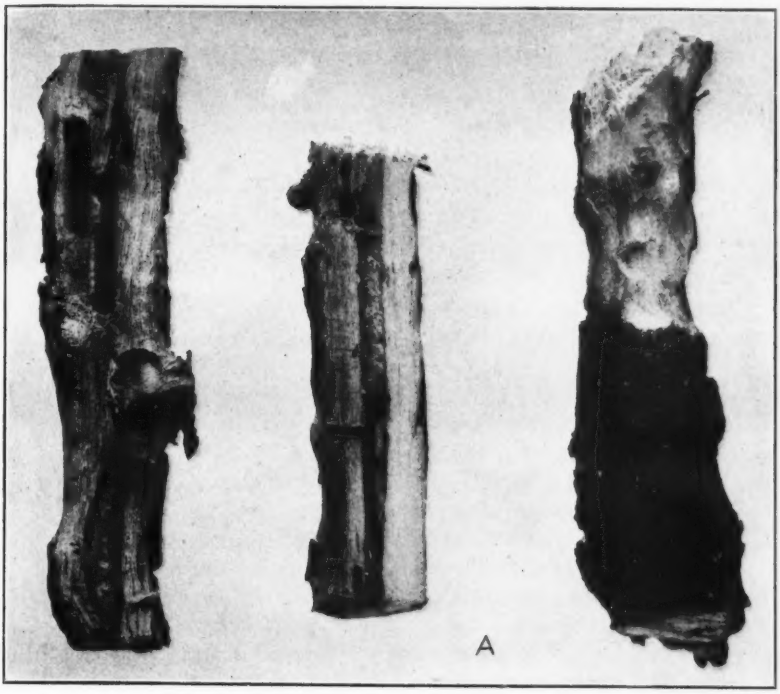
A.—Female. ×2.
B.—Male. ×2.

PLATE 37

Ptychodes trilineatus:

A.—Feeding injury of the larva.

B.—Dead fig tree, showing injury by the three-lined fig-tree borer and other boring insects.


A

B

A STATISTICAL STUDY OF BODY WEIGHTS, GAINS, AND MEASUREMENTS OF STEERS DURING THE FATTENING PERIOD[1]

By B. O. SEVERSON, *Associate Professor*, and PAUL GERLAUGH, *Instructor, The Department of Animal Husbandry, Pennsylvania State Collge Agricultural Experiment Station*

INTRODUCTION

The necessity of judging beef cattle on a more scientific basis than is found in authoritative texts on the subject seems essential. Judgment in general is based on the merits of beef animals gathered from empirical results, and there exists little data on which scientific selection can be made. This necessity exists not only for the selection of breeding animals but for the selection of beef cattle purchased as "feeders." In the case of dairy cattle and the speed horse records of performance are available, and no one disputes their value as a means of selecting animals of merit. The feeder of beef cattle knows that breeding is important and gauges his selection by color markings, size, weight, form, sex, and condition. None of these are definite except sex; the rest are determined by observation, and judgment is made accordingly. Mitchell and Grindley,[2] of Illinois, have shown clearly that the selection of live stock for experimental purposes in many feeding experiments throughout the country has probably been the cause for the large experimental errors that these investigations show.

Is there any method of selection that can be used by experimenters and farmers to determine more accurately the probable gains in live weight and finish of beef cattle under a uniform system of feeding and management. At present the only real definite measurement used in the selection of steers for experimental purposes in feeding is live weight, while the judgment of the experimenter is employed in estimating uniformity of condition, general form, and quality. As shown in Table II of this paper, there is no correlation between live weight and the gains in live weight of steers fed during a fattening period of 140 days. What then can be used as a measure of determining probable gains and lowering the probable error caused by individuality of animals used?

OBJECTS OF THE INVESTIGATION

This paper does not attempt to answer these questions, but has as its object the presentation of information of a nature that may assist others

[1] Presented by permission of the Dean and Director of the School of Agriculture and Agricultural Experiment Station of The Pennsylvania State College.

[2] MITCHELL, H. H., and GRINDLEY, H. S. THE ELEMENT OF UNCERTAINTY IN THE INTERPRETATION OF FEEDING EXPERIMENTS. *In* Ill. Agr. Exp. Sta. Bul. 165, p. 459-579. 8 fig. Bibliography. p. 578-579. 1913.

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Key No. Pa.—3

in making their solution possible. A series of body measurements were made of steers at the beginning and close of feeding experiments for three consecutive years. With these data a starting point for further statistical study is made possible. One object of this paper is to show the average body measurements of 2-year-old steers at the beginning and close of the fattening period caused by fattening and the relationship of other definite body measurements to each other, and to note those measurements that could be used in selection as a means of reducing the experimental error in feeding experiments and a study of variation in the measurements themselves. Another object is to show the correlation of gains to initial body measurements and to changes in body dimensions.

MATERIAL USED

During the winter months of 1914–15,[1] 1915–16,[2] and 1916–17,[3] 72 steers were divided into seven lots each year, a total of 216 animals. These steers were relatively uniform as feeders, varying in market grades from "fair" to "choice," the majority being "good" feeders. These market grades of "fair," "good," and "choice" feeders are illustrated respectively in figures A, B, and C of plate 38. In a total of 207 animals used in this study on which records were made of breeding, as shown by color of hair, 92 were Hereford grades, 84 were Shorthorn grades, 18 were Aberdeen-Angus grades, 7 were Shorthorn × Hereford crosses, 3 were Shorthorn × Aberdeen-Angus crosses, and 3 were Hereford × Aberdeen-Angus crosses. In no case did a steer fail to show some infusion of improved beef blood. The average initial weight of the 216 steers was 900.112 pounds with 700 and 1,300 pounds as extremes. The steers were as uniform in quality, weight, and condition as would ordinarily be obtained for feeding purposes. Each year 60 steers were divided into five lots of 12 each, selected with as much care for uniformity of weight, breeding, condition, and quality as possible.

The feeding of these various lots was done with rations affording very nearly the same opportunity for gains in live weight and condition of flesh for marketing.[4] From the entire group of 72 steers each year 12 "choice" feeders were selected (Pl. 38, C). These 12 steers were fed to "prime" condition and sold as "prime" steers. The 60 steers sold as "good" steers. The feeding period in all cases was 140 days, except those considered in Table II; and the measurements were made within two or three days of the beginning and the close of the feeding period. Table I includes all records for the three years, while the correlation tables (II–VIII) include the data collected during the first two years.

[1] TOMHAVE, W. H., and SEVERSON, B. O. BODY MEASUREMENT OF STEERS. *In* Pa. Agr. Exp. Sta. Ann. Rpt., 1914/15, p. 188–208. 1916.

[2] SEVERSON, B. O., and GERLAUGH, Paul. BODY MEASUREMENT OF STEERS. *In* Pa. Agr. Exp. Sta. Ann. Rpt., 1915/16. (In press.)

[3] ——— ——— and BENTLEY, F. L. BODY MEASUREMENT OF STEERS. *In* Pa. Agr. Exp. Sta. Ann. Rpt. 1916/17. (Not yet published.)

[4] TOMHAVE, W. H., SEVERSON, B. O., and GERLAUGH, Paul. STEER-FEEDING EXPERIMENTS. Pa. Agr. Exp. Sta. Bul. 145, p. 17. 1917.

METHOD OF TAKING MEASUREMENTS

All measurements taken are indicated in Table I. The initial and final weights were averages of individual weights taken on three consecutive days at the beginning and close of the experiments. All body measurements except circumferences were made with the steel calipers shown in Plate 39, A. To the vertical standard, which was graduated in inches, were attached two movable horizontal crossbars. All circumferences were measured with a steel tape graduated in inches (Pl. 39, B).

The steers were tied and placed on a level wooden floor while being measured. Owing to their restlessness, some of the measurements were difficult to obtain, especially those of the head. The measurement of length of neck was discontinued after the second year because of the impossibility of getting correct position and dimensions. The distance from hock to ground was another measurement which possessed a large experimental error. The probability of error in measurements is a factor not considered, thus necessitating a larger number of measurements to reduce the probable error.

METHOD OF CALCULATION[1]

The method of calculation in the tables presented were as follows:[2]

The mean was obtained by the following formulæ: $A = \frac{\Sigma D^1 f}{n} + H.$

The standard deviation was calculated as follows: $\sigma = \frac{\sqrt{\Sigma (D^1)^2 f}}{n} - \frac{(\Sigma D^1 f)^2}{n}$

The coefficient of correlation coefficient was worked by the formulæ: $r = \frac{\Sigma D x D y f}{n \sigma x \sigma y}.$

The coefficient of variation was obtained as follows: $C = \frac{\sigma}{a} \times 100$ per cent.

The probable error in each was determined as follows:

Probable error of mean: $E_A = \pm 0.6745 \frac{\sigma}{\sqrt{n}}$;

Probable error of standard deviation: $E\sigma = \pm 0.6745 \frac{\sigma}{\sqrt{2n}}$;

Probable error of coefficient of correlation: $Er = \pm 0.6745 \frac{(1 - r^2)}{\sqrt{n}}$;

Probable error of coefficient of variation: $E_c = \pm 0.6745 \frac{C}{\sqrt{2n}}$.

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[1] DAVENPORT, C. B. STATISTICAL METHODS, WITH SPECIAL REFERENCE TO BIOLOGICAL VARIATION. ed. 3, p. 12–18, 44–45. New York and London, 1914.

[2] KEY TO FORMULÆ:

A = Means;
σ = Standard deviation;
r = Coefficient of correlation;
C = Coefficient of variation;
n = Population;
Σ = Summation;
H = Assumed mean;
x = Character classified in vertical columns;
y = Character classified in horizontal row;
D^1 = Deviation from assumed mean.
f = Frequency.

TABLE I.—*Average initial and final measurements of 2-year-old steers fattened for market during a 140-day feeding period*

Measurement.	Initial measurement.		Final measurement.		Difference in measurements.	Percentage increase.
	Number of steers.	Average.	Number of steers.	Average.		
		Pounds.		*Pounds.*	*Pounds.*	
Weight	216	900.112	216	1,188.398	288.286	32.02
		Inches.		*Inches.*	*Inches.*	
Width of head	214	8.832	216	9.112	.280	3.16
Length of head	214	19.411	216	19.892	.481	2.48
Length of neck	103	19.163	72	20.990	1.827	9.53
Width of shoulders	214	16.412	215	18.459	2.047	12.42
Width of front flank	214	16.378	216	18.358	1.980	12.08
Width of paunch	214	23.612	216	26.101	2.489	10.54
Width of rear flank	154	19.527	216	22.744	3.217	16.42
Width of loin	209	13.984	216	15.958	1.974	14.11
Width of hips	202	17.662	216	19.254	1.592	9.01
Width of thurls[a]	209	17.204	215	18.533	1.329	7.72
Buttock to hip	214	18.366	216	19.622	1.256	6.83
Depth of chest	154	26.730	215	27.789	1.059	3.96
Shoulder point to ground	214	33.033	216	34.311	1.278	3.86
Chest to ground	214	22.876	216	23.013	.237	1.03
Hind flank to ground	214	29.128	216	30.202	1.074	3.68
Hock to ground	142	20.795	204	20.914	.119	.57
Withers to ground	214	49.224	216	53.870	4.646	9.43
Hips to ground	202	50.855	214	52.411	1.556	3.05
Shoulder to buttock	214	53.763	216	57.988	4.225	1.85
Circumference of chest	214	73.014	216	77.694	4.680	6.40
Circumference of paunch	214	80.256	216	88.301	8.045	10.02
Circumference of hind flank	214	71.364	216	78.685	7.321	10.25
Circumference of muzzle	141	17.198	143	17.930	.832	4.83

[a] Hip joint.

These 216 steers used during the three years of 1914 and 1917, inclusive, were 2-year-olds, averaging in weight 900.112 pounds as "feeders" and 1,188.398 pounds as market animals, and gained at the rate of 2.058 pounds daily for 140 days. Although the steers were divided into six lots each year, they were in all cases finished into market steers varying from "medium" to "choice," the greater proportion being graded as "good" steers.

The following average initial measurements show a marked similarity: the length of head, length of neck, and width of rear flank, which vary from 19.163 to 19.527 inches; the width of shoulder and front flank differ by only 0.034 inch; the hips and thurls (hip joint) in width are 17.682 inches and 17.204 inches, respectively; and circumference of the body in the region of the chest and hind flank are 73.014 and 71.364 inches, respectively. The height at the withers of a "feeder" steer is 1.631 less than the height at the hips. The length of body from shoulder point to buttock is only 2.908 inches greater than the greatest height at the hips.

The average measurements at the conclusion of the fattening period show similarity as follows: The length of head, width of hips, and distance of buttock from hips varying within 0.638 inch of each other; the width of shoulder, front flank, and thurls are almost identical; and the circumference of the chest and hind flank are more alike than their initial measurements. The height has increased more at the withers than at the hips; thus, a 2-year-old steer changes his greatest height from the hips to the withers while receiving market condition. In circumference the increase was greater for the hind flank than for the chest; thus, the greater circumference of the chest at the initial measurement becomes less than the circumference of the hind flank in the finished steer. In fattening, the greatest width at paunch and the greatest depth of body at the chest become more nearly alike, as shown by a difference of 3.118 inches at the initial measurement and 1.688 inches at the concluding measurement.

In all cases the difference between the initial measurement and the final measurement shows an increase in dimensions due to deposition of fat, muscular development, and growth. The regions of the body covered by the greatest amount of muscular development show greater increased dimensions than those having less muscular covering. In the regions where the growth would show the greater relative influence the least changes take place as shown in the width of head, length of head, distance from chest to ground and hock to ground. The greatest increase in width took place in the hind flank rather than in the paunch, where it would seem natural to have the greatest increase because of feed capacity and condition. The thick layer of flesh and fat deposits in the region of the hind flank, together with the distention of this region of the body in a fattened steer, are responsible for the greater width in this part of the body. The width of loin, hips, thurls, shoulders, and front flank shows changes in dimensions caused mainly by increased condition of flesh.

The increase in height at the withers of 4.646 inches is not all due to growth alone, a larger portion of this increase being caused by the flesh covering over the withers and the deposition of fat in the muscular tissues of the shoulder region. The fat deposit and muscular development causes the shoulder blade to be held more rigidly; thus, the body in the chest region rises between the shoulder blades, as indicated by the greater distance between the withers and the upper border of the shoulder blade. The greatest change in the body measurements was the circumference of the paunch. This, however, was proportionately less than the increase of 7.321 inches in circumference of the hind flank. The fact that the distance of chest to ground and hind flank to ground did not show greater difference was due to the lowering of the flank by deposition of fat in that region and the fat covering over the region of the chest. The region

of the body possessing the most valuable eatable parts on the whole are affected most in the fattening process.

The percentage of increase of the final measurements as compared with the initial measurements shows that increased weight was 32.02 per cent, the greatest increase of all measurements. The measurements that showed more than 10 per cent increase were width of shoulder, front flank, paunch, rear flank, loin and circumferences of paunch and hind flank. Those which increased from 5 to 10 per cent were as follows: Length of neck, width of hips, width of thurls, distance from buttock to hip, height at withers, distance from shoulder point to buttock, and circumference of chest. Measurements that showed less than 5 per cent increase were: Width and length of head, depth of chest, distance from shoulder point to ground, from chest to ground, from hock to ground, from hip to ground, and the circumference to muzzle. Thus, again it is seen that the greatest relative changes in body dimensions occur in the regions affected most by deposition of fat and muscular development.

CORRELATION TABLES (II–VI)

The following correlation tables (II–VI) are presented as illustrations of the methods used in obtaining the facts presented in Tables VII and VIII.

TABLE II.—*Correlation of average daily gain of steers during a feeding period of 120 to 140 days and the weight at the beginning of the feeding period*

Daily gain (pounds).	Initial weight per steer (pounds).													
	1,300	1,250	1,200	1,150	1,100	1,050	1,000	950	900	850	800	750	700	Total.
3.2	....	....	....	....	....	....	....	1	....	....	....	....	....	1
3.0	....	....	....	....	....	....	....	....	....	....	....	....	....	0
2.8	....	....	....	....	1	1	3	1	1	2	1	1	....	11
2.6	....	....	....	....	....	4	2	2	4	1	3	3	1	20
2.4	....	1	....	1	2	1	5	8	11	7	6	3	2	47
2.2	....	1	....	2	2	....	4	7	4	7	4	5	....	36
2.0	1	1	....	3	....	1	4	7	9	16	9	12	2	65
1.8	....	1	....	3	2	2	5	7	11	10	9	7	6	63
1.6	....	....	1	....	....	1	5	3	5	4	4	5	4	32
1.4	....	....	....	1	2	....	4	4	10	3	7	1	1	33
1.2	....	....	2	....	....	2	2	4	2	6	2	1	1	22
1.0	....	....	....	....	....	....	....	1	2	....	1	1	....	5
.8	....	....	....	....	....	1	....	....	2	....	....	....	....	3
Total	1	4	3	10	9	13	34	45	61	56	46	39	17	338

Mean live weight	pounds	893.93	±3.94
Mean daily gain	do	1.95	± .016
Standard deviation of live weight	do	106.88	±2.77
Standard deviation of daily gain	do	.446	± .011
Correlation		.0364	± .0366

According to the literature cited,[1] there is some difference of opinion as to the average daily gain of steers of different ages which in reality is a difference in live weight, because, other things being equal, a steer when 2 years old will weigh more than a yearling. Table II shows a correlation of 0.0364, with a probable error of ±0.0366. The population includes 338 steers fed at The Pennsylvania State College during eight years. The correlation shows that there is no relation between the daily gain which may be expected from various weights of feeders of a fairly close range in age and condition.

TABLE III.—*Correlation of the initial circumference of chest of steers with gain in live weight during a 140-day feeding period*

Gain in weight (pounds).	Initial circumference of chest (inches).																			
	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64	63	62	61	60	Total.
410						1				1										2
390	1					1		1	1											4
370					3	1	1		1	1		1								8
350				1	1	3	1	1	2				1							10
330			1		2	1	2	1	4	2		3	1	1						18
310			1			1	3	2	3	2	2	2		1	1					18
290				2	1	1		2	6	4	2	3	2			2				25
270			1				4	1	1		1	3	1		1					13
250				1		2	4	3	2	3		1	1		1					18
230					1	2			1		2		1	1	1	1	1			11
210					1				1	1	2		1							6
190			1							2	2									5
170									1		1								1	3
150													1							1
Total	1	0	4	4	9	13	15	11	23	16	12	13	9	3	4	3	1	0	1	142

Mean gain	pounds..	288.87 ±3.06
Mean circumference of chest	inches..	69.824±0.221
Standard deviation of gain	pounds..	54.180±2.168
Standard deviation of circumference of chest	inches..	3.910±0.015
Correlation		.238±0.053

The circumference of chest as an indication of the ability of a steer to make rapid gains is indicated here by the correlation 0.238±0.053. The spring of rib and depth of chest are regarded as indications of rapid gains by buyers. The circumference of the chest is of greater importance than the width or depth, as shown by these results.

[1] HENRY, W. A., and MORRISON, F. B. FEEDS AND FEEDING. ed. 15, p. 451. Madison, Wis., 1915.
WOLL, F. W. PRODUCTIVE FEEDING OF FARM ANIMALS. p. 258. Philadelphia and London, 1915.

TABLE IV.—*Correlation of increase of circumference of chest and gain in live weight of steers during a 140-day feeding period*

Gain in weight (pounds).	Increase in circumference of chest (inches).											
	12.5	11.5	10.5	9.5	8.5	7.5	6.5	5.5	4.5	3.5	2.5	Total.
412.5	1		1									2
387.5			1	1	2	1	1					6
362.5	2		2	2	2	1						9
337.5		2	5	3	6	4	2		1			23
312.5		1	2	5	3	4	5					20
287.5		1	3	5	7	6	4	1	1			28
262.5				2	4	4	3	2			1	16
237.5			1	3	4	4	8			1		21
212.5					3	2	1	1		1		8
187.5					1			3	2			6
162.5		1			1			1				3
Total...	3	5	15	21	33	26	24	8	4	2	1	142

Mean gain	pounds..	288.5 ±3.101
Mean increase in chest circumference	inches..	8.13±0.105
Standard deviation in gain	pounds..	54.77±2.193
Standard deviation of gain in chest circumference, inches		1.87 ±0.074
Correlation		.460±0.044

The increase in the circumference of the chest varied from 2.5 to 12.5 inches, most of the steers showing an increase of 6.5 to 9.5 inches. Table II shows that the steers having a large increase in the circumference of the chest have been those steers that had made the greatest daily gains. (It is true that the more a steer gains the greater is the amount of covering of flesh over the ribs or around the chest circumference.)

TABLE V.—*Correlation of the initial width of the thurls with the gain in live weight of steers during a 140-day feeding period*

Gain in weight (pounds).	Initial width of thurls (inches).											
	20.25	19.75	19.25	18.75	18.25	17.75	17.25	16.75	16.25	15.75	15.25	Total.
412.5				1								1
387.5	1	1	1	1	1							5
362.5					1	2	3	1	1			8
337.5					3	5	7	2	3	1		21
312.5				6	1	2	2	3	4	1		19
287.5					4	7	7	4	5	1		28
262.5		2	1	1	1	1	4	4		2		16
237.5			2		1	5	6	2	2	2	1	21
212.5				1	1	1	1		4			8
187.5			2		1				2		1	6
162.5								1		2		3
Total...	1	3	6	10	14	23	30	17	21	9	2	136

Mean gain	pounds..	285.48 ±3.097
Mean width of thurls	inches..	17.36 ±0.059
Standard deviation of gain	pounds..	53.55 ±2.185
Standard deviation of width of thurls	inches..	1.03 ±0.041
Correlation		.224±0.054

The width of the thurls is shown here to be a measurement which should be given considerable emphasis in foretelling the gaining capacity of steers. It is a measurement which usually is overlooked, but the correlation shows that it is more important than many measurements usually regarded as especially important.

TABLE VI.—*Correlation of the initial distance from chest to ground with gain of steers during a 140-day feeding period*

Gain in weight (pounds).	Distance from chest to ground (inches).								
	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	Total.
412.5	.....	.....	.....	.....	1	1	.....	.....	2
387.5	.....	.....	.....	1	1	2	1	1	6
362.5	.....	.....	.....	4	1	1	2	1	9
337.5	.....	.....	.....	6	7	8	2	.....	23
312.5	1	.....	2	1	6	6	2	2	20
287.5	.....	.....	1	8	4	6	3	6	28
262.5	.....	1	.....	3	5	5	2	.....	16
237.5	.....	.....	2	5	8	3	2	1	21
212.5	.....	.....	.....	1	2	1	4	.....	8
187.5	.....	.....	.....	2	2	2	.....	.....	6
162.5	.....	.....	.....	1	1	1	.....	.....	3
Total	1	1	5	32	38	36	18	11	142

Mean gain	pounds..	288.55 ±3.101
Mean distance from chest to ground	inches..	22.89 ±0.066
Standard deviation of gains	pounds..	54.77 ±2.192
Standard deviation of distance from chest to ground	inches	1.18 ±0.047
Correlation		.077±0.056

The distance from chest to ground does not show sufficient correlation with the gain to become an important factor in determining the choice of "feeder" steers, as shown by these results.

The results shown in Table VII are based on data collected on steers during the two winter periods of 1914–15 and 1915–16. All measurements considered in this table are initial measurements, except those that show increases of dimensions at the close of the fattening period as compared with initial measurements. The coefficient of variation is shown to be greatest on increases in circumferences of hind flank, paunch, and chest, and the increase of gains in live weight.

These measurements all relate to increased dimensions and occur in those parts of the body that show relatively high percentage increase over initial body measurements (Table I).

Of the initial measurements the greatest coefficient of variation is 11.9±0.04 per cent for initial live weight.

In all the chest measurements the coefficients of variation are relatively high: Width at point of shoulder 9.3±0.52, width of fore flank 10.4±0.6, depth of chest 6.1±0.34, and circumference of chest 6.9±

0.39. Likewise the mid and posterior regions of the body show variations, the rear flank with a coefficient of variation of 8.7±0.48, circumference of rear flank 6±0.34, width of loin 7.5±0.43, width of thurls 5.9±0.34, circumference of paunch 11±0.62, and distance of hip to buttock 5.2±0.29.

The measurements affected most by growth show the least variations and include the distance of shoulder point, rear flank, and withers from the ground, length of head, and distance of shoulder point to buttock. In general, Table VII shows the greatest variation in those regions of the body which change most in a fattening steer and those regions affected most by deposition of fat and development of muscular tissue.

TABLE VII.—*Means, standard deviations, and coefficients of variations shown in correlation tables*

Number of steers.	Measurement.	Mean.	Standard deviations.	Coefficient of variation.
				Per cent.
338	Average daily gain.....pounds..	1.93±0.016	0.446±0.011	23.1±0.84
338	Initial live weight.....do....	893.93±3.94	106.88 ±2.77	11.9± .04
142	Total gain in live weight...do....	288.55±3.10	54.77 ±2.19	19.1±1.08
142	Increase in circumference of chest.....inches..	8.13± .10	1.87 ± .074	23.0±1.30
142	Width of rear flank.....do....	19.25± .09	1.69 ± .06	8.7± .48
142	Circumference of rear flank, inches.....	72.76± .25	4.40 ± .17	6.0± .34
142	Height of shoulder point..inches..	34.10± .08	1.57 ± .06	4.5± .25
142	Height of rear flank.....do....	30.23± .09	1.67 ± .06	5.5± .31
142	Distance, hip to buttock...do....	18.69± .05	.99 ± .03	5.2± .29
137	Width of loin.....do....	13.96± .06	1.05 ± .22	7.5± .43
142	Circumference of chest....do....	69.82± .22	3.91 ± .01	6.9± .39
142	Depth of chest.....do....	25.77± .08	1.59 ± .063	6.1± .34
142	Width of fore flank.....do....	15.02± .08	1.57 ± .06	10.4± .60
142	Distance chest to ground...do....	22.89± .06	1.18 ± .04	5.1± .28
136	Width of thurls.....do....	17.36± .05	1.03 ± .04	5.9± .34
142	Length of head.....do....	19.53± .04	.81 ± .03	4.1± .23
142	Length of shoulder to buttock, inches.....	55.66± .17	3.02 ±2.84	5.4± .30
142	Increase in circumference of paunch.....inches..	8.26± .16	2.96 ± .11	35.8±2.02
142	Height at withers.....do....	49.50±1.07	1.95 ± .07	4.9± .27
142	Width at point of shoulder..do....	16.42± .08	1.54 ± .06	9.3± .52
142	Circumference of paunch...do....	81.60± .56	10.04 ±4.02	11.0± .62
138	Increase in circumference of rear flank.....inches..	7.52± .20	3.51 ± .14	46.6±2.67

TABLE VIII.—*Summary of correlations*

Correlating—	Correlation coefficient.	Correlating—	Correlation coefficient.
Gain with initial live weight	0.036±0.036	Gain with initial length of head	0.182±0.037
Gain with increase in circumference of chest	.460± .044	Gain with initial length from point of shoulder to buttock	−.020± .056
Gain with initial width of rear flank	.079±. 083	Gain with increase in circumference of paunch	.306± .036
Gain with initial circumference of rear flank	.221± .053	Gain with initial height of withers	.163± .054
Gain with initial height of point of shoulder	.061± .056	Gain with initial width of shoulders	.144± .055
Gain with initial height of rear flank	.053± .055	Gain with initial circumference of paunch	.124± .055
Gain with initial length of hip to buttock	.271± .053	Gain with increase in circumference of rear flank	.203± .055
Gain with initial width of loin	.108± .085	Width of thurls with height of rear flank	.380± .049
Gain with initial circumference of chest	.238± .053	Circumference of chest with height of withers	.621± .034
Gain with initial depth of chest	.130± .046	Width of loin with height of chest from ground	.179± .057
Gain with initial width of fore flank	.164± .054	Width of chest with depth of chest	.365± .072
Gain with initial distance of chest to ground	.077± .056		
Gain with initial width of thurls	.224± .054		

Table VIII, a summary of the coefficients of correlation, shows that increases in body measurements have a closer relationship with gains in live weight than the initial measurements. This would logically be expected, since gains are dependent upon the capacity of a steer to lay on fat and make growth in bone and body tissue. With the exception of initial weight, these measurements, as shown in Table VII, also had high coefficients of variation.

The correlation coefficients for the two body circumferences of chest and rear flank, the width of thurls (hip joint), and the distance of hip to buttock show the closest relationship of all the initial measurements with gains in live weight. This suggests the possibilities of using these measurements in the selection of feeding steers, at least for experimental purposes, as a means of reducing the experimental error caused by individuality of animals. The measurement of initial weight shows no relationship with gains, although this is usually considered one of the most important factors in selection of steers for experimental purposes.

Measurements that show intermediate relationship as indicated by coefficients of correlation are width of loin, depth of chest, width of fore flank, length of head, height at withers, circumference of paunch, and width at shoulders.

Measurements in which slight or no relationship exist as shown by correlation coefficients are initial live weight, width of rear flank, height at shoulder point, and the distance of rear flank and chest from the ground. One measurement, the distance of shoulder point to buttock, showed a negative correlation of -0.020 ± 0.056, but in which the probable error was greater than the correlation coefficient.

A close relationship of circumstance of chest with height of withers is indicated by $r = 0.621 \pm 0.034$. Likewise, the width of chest and depth of chest by $r = 0.365 \pm 0.072$ show a definite relationship.

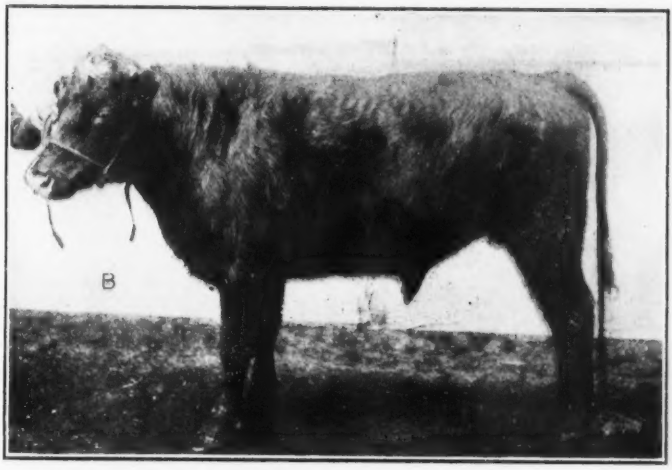
The hind quarters of a steer are more important than the fore quarters in determining the gaining capacity of a steer, with the exception of the circumference of chest as shown by a correlation coefficient of 0.224 ± 0.054 for width of thurls, 0.271 ± 0.053 for distance of hip to buttock, and 0.221 ± 0.053 for circumference of rear flank.

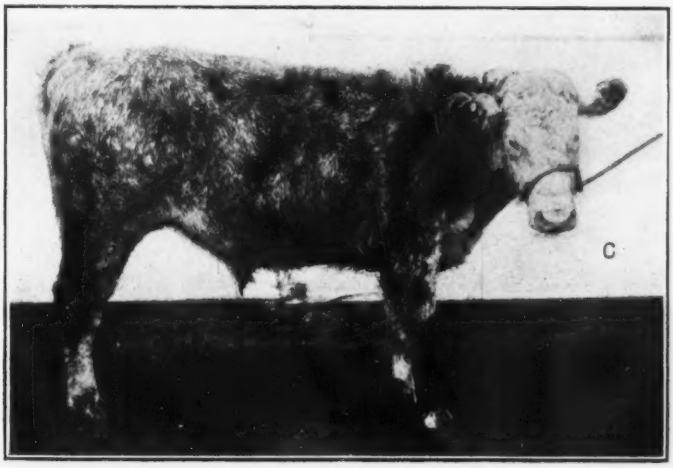
The following points, held by authoritative judges of live stock to be important, are not substantiated by the results of this study thus far: Initial weight of steers, closeness to the ground of chest and hind flank, and the length of body from shoulder to buttock. The circumference of chest and rear flank are more important in ascertaining gains than feed capacity as indicated by the circumference of paunch.

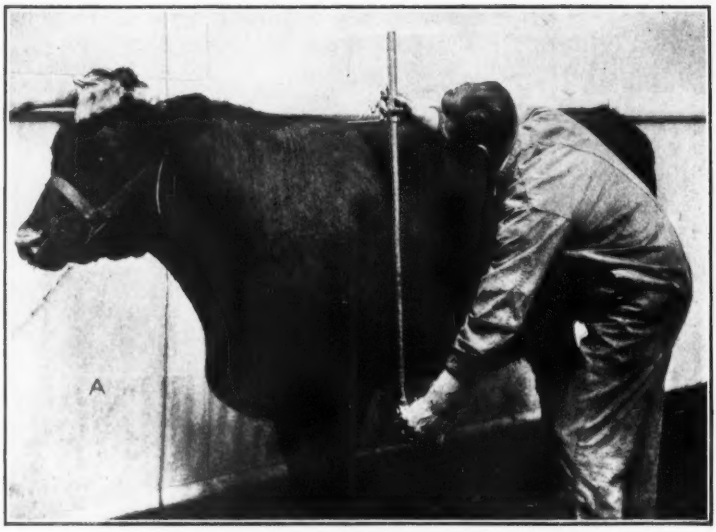
PLATE 38

A.—A "fair feeder" showing infusion of some Shorthorn blood.
B.—A "good feeder" of Shorthorn breeding.
C.—A "choice feeder" of Shorthorn breeding.

A


B


C


A

B

PLATE 39

A.—Measuring the depth of the chest of a steer with calipers.
B.—Measuring the circumference of the chest of a steer.

LIFE HISTORY OF ASCARIS LUMBRICOIDES AND RELATED FORMS

[PRELIMINARY NOTE]

By B. H. RANSOM, *Chief*, and W. D. FOSTER, *Junior Zoologist, Zoological Division, Bureau of Animal Industry, United States Department of Agriculture*

Recently Capt. F. H. Stewart,[1] of the Indian Medical Service, in several publications has recorded the results of some experiments of great importance in the light which they throw upon the question of the life history of *Ascaris lumbricoides*, the common intestinal roundworm of man. The same parasite, or a form so closely related that it is morphologically indistinguishable so far as our present knowledge goes, is of very common occurrence in the intestine of pigs (*A. suum* or *A. suilla*). Stewart used both forms in his experiments. He failed in his attempts to infect pigs but found that if rats or mice were fed Ascaris eggs, the eggs hatched in the alimentary tract, and the embryos migrated to the liver, spleen, and lungs. In the course of their migrations they increased in size and passed through certain developmental changes, many of them finally reaching the alimentary tract again by way of the lungs, trachea, and esophagus. The young worms that succeeded in regaining the alimentary tract did not continue their development and soon passed out of the body in the feces, so that rats or mice surviving the pneumonia commonly caused by the invasion of the lungs became free of the parasites as early as the sixteenth day after infection.

As a result of his investigations Stewart was led to a conclusion contrary to the usually accepted opinion that the infection of man or pig with Ascaris results from the ingestion of the eggs of the parasite. He concluded that it is necessary in the life cycle for the eggs to be swallowed by rats or mice and that in these animals the embryos hatching from the eggs undergo certain migrations and developmental changes, after which they may be transferred in the feces or saliva of the rats or mice to food or other materials likely to be ingested by human beings or pigs, and thus ultimately reach their final hosts.

[1] STEWART, F. H. ON THE LIFE-HISTORY OF ASCARIS LUMBRICOIDES. *In* Brit. Med. Jour., 1916, v. 2, no. 2896, p. 5–7, 3 fig. 1916.

———. THE LIFE-HISTORY OF ASCARIS LUMBRICOIDES. *In* Brit. Med. Jour., 1916, v. 2, no. 2909, p. 474. 1916.

———. FURTHER EXPERIMENTS ON ASCARIS INFECTION. *In* Brit. Med. Jour., 1916, v. 2, no. 2910, p. 486–488, 1916.

———. ON THE LIFE-HISTORY OF ASCARIS LUMBRICOIDES. *In* Brit. Med. Jour., 1916, v. 2, no. 2918, p. 753–754, 1916.

———. ON THE DEVELOPMENT OF ASCARIS LUMBRICOIDES LIN. AND ASCARIS SUILLA DUJ. IN THE RAT AND MOUSE. *In* Parasitology, v. 9, no. 2, p. 213–227, 9 fig., 1 pl. 1917.

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In reviewing Stewart's work it appeared to us that, granting the correctness of his observations, the conclusions that he had drawn did not supply an adequate explanation of the mode of infection with Ascaris. On a number of occasions we had endeavored to infect pigs with Ascaris by feeding the and eggs, although the results of these attempts had been negative or uncertain and thus in harmony with the experience of Stewart and other investigators, we nevertheless did not feel justified in accepting these results as evidence against the hypothesis of a direct development without an intermediate host, nor did it seem that Stewart's experiments with rats and mice were sufficient to lead to the conclusion that these animals act in any way as intermediate hosts in the life cycle of the parasite.

Repetition of Stewart's experiments in feeding rats and mice with Ascaris eggs gave results agreeing very closely with those which he has recorded. We have noted wider variations as to the time at which the larvæ may be found in various organs and have observed them in several locations in addition to those in which they were seen by Stewart, but the results of our experiments were essentially the same as his, and point to a migration of the larvæ to the liver, lungs, spleen, and other organs, and finally from the lungs to the alimentary tract by way of the air passages through the trachea and into the esophagus, during which migrations they undergo considerable development and structural change and increase to a size of 1.5 mm. or more in length.[1] In most of our experiments the eggs of the pig Ascaris were used, as Ascaris from pigs was more easily obtainable than parasites from human beings. In addition to our experiments on rats and mice we made further attempts, with negative results, to infect pigs.

Our unsuccessful attempts to infect pigs by feeding Ascaris eggs were made on animals several months old.[2] It is noteworthy that Epstein,[3] in his carefully controlled experiments with *A. lumbricoides* used very young subjects and that the positive results which he obtained can scarcely be explained upon any other assumption than that a direct development of the parasites occurred following feeding of the eggs—that is, development without an intermediate host. The experience of one of us (B. H. R.) in certain investigations[4] on the life history of *Syngamus trachealis*, our failures, and the failures of others to infect pigs with Ascaris, the fail-

[1] Since the preparation of this manuscript further investigations have shown that guinea pigs as well as rats and mice may be infected by feeding Ascaris eggs. In these animals the migration of the larvæ was, as far as observed, identical with that noted by Stewart for rats and mice. All of the six infected guinea pigs died from pneumonia between seven and eight days after feeding with Ascaris eggs, the lungs being heavily infested with Ascaris larvæ.

[2] The pigs which Stewart used with negative results were stated by him to have been 2 months old. The ages of the animals used by various other investigators who failed to obtain positive results in experiments to bring about infestations by feeding the eggs of Ascaris are generally not stated, but in many of the negative experiments with human beings it is clear that adults were used as subjects.

[3] EPSTEIN, Alois. UEBER DIE UEBERTRAGUNG DES MENSCHLICHEN SPULWURMS (ASCARIS LUMBRICOIDES). *In* Verhandl. Versamml. Gesell. Kinderh. Deut. Naturf. u. Aerzte, v. 9, 1891, p. 1-16. 1892.

[4] Not yet published.

ures of various investigators to infect adult human beings, and Epstein's positive results in the case of young subjects, suggested the possibility that age is an important factor influencing the susceptibility of human beings and pigs to infection with Ascaris, and that many of the failures to bring about experimental infections would not have occurred if younger animals had been used as subjects. Our belief in this possibility was strengthened by the discovery of an Ascaris larva in a fragment of lung from a pig about 6 weeks old which had died from unknown causes in May, 1917, a finding which indicated a migration of larvæ like that which occurs in rats and mice. The intestine of this pig contained numerous immature ascarids, the largest about 5 cm. long. In order to test the possibility of infecting very young pigs, after several disappointments because certain sows reserved for the purpose of providing young pigs for experimental use either failed to farrow or devoured their newborn offspring, we finally succeeded in obtaining two young pigs from a sow which was found by fecal examination to be free from egg-producing ascarids. In the latter part of September, at the age of about 2 weeks, one of these pigs was given a large number of Ascaris eggs containing motile vermiform embryos. The number of eggs given was not determined, but there must have been at least several thousand. One week after feeding the pig which had been fed with Ascaris eggs was brought into the laboratory dead; death had occurred either the same day or late the day before; in any event, approximately one week had elapsed since the animal had been given a heavy dose of Ascaris eggs. The other pig continued in good health. Examination of the dead pig revealed a pneumonia, with numerous petechial hemorrhages in the lung tissue. Numerous ascarid larvæ, varying in length from 0.7 to 1.2 mm. in length, were found in the lungs, trachea, and pharynx; none in the liver, spleen, esophagus, small intestine, or large intestine.

It is of interest to note in this connection that when rats or mice are fed large numbers of Ascaris eggs they commonly die of pneumonia about a week later, at a time when numerous larvæ are present in the lungs, exactly as in the case of this pig. These findings are interpreted by us as clearly demonstrating that Ascaris larvæ in young pigs, presumably also in children, behave in much the same way as in rats or mice, and strongly support the hypothesis that the migrations and development of the parasites are very similar in the two cases, the only important difference being that in rats or mice the worms are unable to continue their development to maturity.

Stewart's very important discoveries concerning the behavior of Ascaris larvæ in rats and mice, the various contributions of other investigators toward the solution of the problem of the life history of *A. lumbricoides* and related parasites, and our own experiences outlined above, appear to justify certain conclusions, some of which in anticipation

of a more extended statement in a future paper, may be briefly given as follows:

The development of *A. lumbricoides* and closely related forms is direct, and no intermediate host is required.

The eggs, when swallowed, hatch out in the alimentary tract; the embryos, however, do not at once settle down in the intestine, but migrate to various other organs, including the liver, spleen, and lungs.

Within a week, in the case of the pig Ascaris, the migrating larvæ may be found in the lungs and have meanwhile undergone considerable development and growth.

From the lungs the larvæ migrate up the trachea and into the esophagus by way of the pharynx, and this migration up the trachea may already become established in pigs, as well as in artificially infected rats and mice, as early as a week after infection.

Upon reaching the alimentary tract a second time after their passage through the lungs, the larvæ, if in a suitable host, presumably settle down in the intestine and complete their development to maturity; if in an unsuitable host, such as rats and mice, they soon pass out of the body in the feces.

Heavy invasions of the lungs by the larvæ of Ascaris produce a serious pneumonia which is frequently fatal in rats and mice and apparently caused the death of a young pig one week after it had been fed with numerous Ascaris eggs.

It is not improbable that ascarids are frequently responsible for lung troubles in children, pigs, and other young animals. The fact that the larvæ invade the lungs as well as other organs beyond the alimentary tract and can cause a serious or even fatal pneumonia indicates that these parasites are endowed with greater capacity for harm than has heretofore been supposed.

Age is a highly important factor in determining susceptibility to infection with Ascaris, and susceptibility to infection greatly decreases as the host animal becomes older. This, of course, is in harmony with the well-known fact that it is particularly children and young pigs among which infestation with Ascaris is common, and that Ascaris is relatively of rare occurrence in adult human beings and in old hogs.